EDISON
ELECTRIC INSTITUTE
BULLETIN

GEOGRAPHY, RESOURCES & INDUSTRIES

JULY, 1940

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EDISON ELECTRIC INSTITUTE

THE ELECTRIC LIGHT AND POWER INDUSTRY

Current Statistical Data Covering 100 Per Cent of Industry

CLASSIFICATION OF SALES (Revised Series)

	1940	1939	%
Number of Customers as of APRIL 30th			
Residential or Domestic	24,221,593	23,449,671	+ 3.3
Rural (Distinct Rural Rates)	652,071	577,450	+12.9
Commercial or Industrial:			
Small Light and Power	4,200,994	4,157,310	+ 1.1
Large Light and Power	178,711	185,055	− 3.4
Street and Highway Lighting	23,887	24,872	.....
Other Public Authorities	88,390	77,777	.....
Railways and Railroads:			
Street and Interurban Railways	209	225	.....
Electrified Steam Railroads	28	31	.....
Interdepartmental	1,142	1,119	.....
Total Ultimate Customers	**29,367,025**	**28,473,510**	**+ 3.1**
Kilowatthour Sales During Month of APRIL			
Residential or Domestic	1,856,256,000	1,700,817,000	+ 9.1
Rural (Distinct Rural Rates)	123,930,000	125,481,000	− 1.2
Commercial or Industrial:			
Small Light and Power	1,757,999,000	1,635,203,000	+ 7.5
Large Light and Power	4,610,728,000	3,889,239,000	+18.6
Street and Highway Lighting	154,937,000	152,324,000	+ 1.7
Other Public Authorities	220,912,000	204,328,000	+ 8.1
Railways and Railroads:			
Street and Interurban Railways	325,533,000	323,826,000	+ 0.1
Electrified Steam Railroads	156,112,000	150,618,000	+ 3.6
Interdepartmental	63,490,000	61,581,000	+ 3.1
Total Ultimate Customers	**9,269,897,000**	**8,243,417,000**	**+12.5**
Revenue from Ultimate Customers	**$194,414,600**	**$183,265,800**	**+ 6.1**

RESIDENTIAL OR DOMESTIC SERVICE (Revised Series)

Average Customer Data for the 12 months ended APRIL 30th			
Kilowatthours per Customer	916	869	+ 5.4
Average Annual Bill	$36.09	$35.54	+ 1.5
Revenue per Kilowatthour	3.94¢	4.09¢	− 3.7

GENERATION FOR THE U. S. POWER SUPPLY AS A WHOLE FOR THE MONTH OF APRIL

	1940	1939	%	1938	1937
Fuel	6,423,215	5,363,065	+ 19.8	4,709,378	5,537,224
Hydro	4,456,120	4,306,690	+ 3.5	3,999,374	4,102,257
Total	**10,879,335**	**9,669,755**	**+ 12.5**	**8,708,752**	**9,639,481**

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EDISON ELECTRIC INSTITUTE BULLETIN

Volume 8 JULY, 1940 No. 7

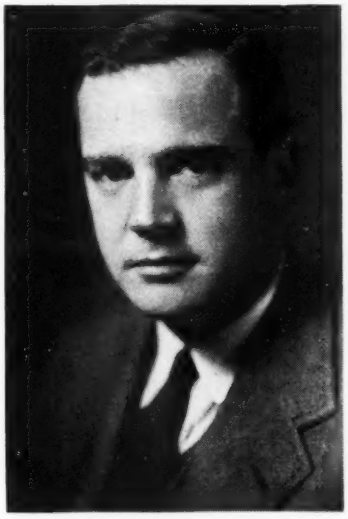
American Free Enterprise and the Future

By Philip D. Reed

Chairman of the Board, General Electric Company

From a recent address before the University of Wisconsin Alumni Club of Milwaukee

WE have come a long way in the last hundred years from the days when our population was but a fraction of its present 130 odd million, when economic, social and political problems were far less complex, when town hall meetings were held in thousands of communities to discuss problems of national and local import, and when therefore democracy was in a sense bulwarked by a relatively well informed electorate. Today, let us quickly concede, the task of keeping even reasonably well informed on national problems is an almost overwhelming one. But if we cease to try, we are surely lost. I have great confidence in collective wisdom and can imagine nothing finer for this nation of ours than if all of us would spend some time each day, thirty minutes perhaps, reading not simply the headlines but articles and editorials on current problems with which we are unfamiliar.



MR. REED

It is interesting that through the ages (although it is less true today) those in possession of specialized knowledge have, perhaps unconsciously, shielded that knowledge from and magnified it in the eyes of the uninitiated. The doctor with his Latin terms for common ailments and his unreadable prescriptions, the lawyer with his antique, and to the laymen incomprehensible, verbiage, the engineer and the chemist with their symbols, terms and formulae that defy understanding except by those similarly trained, and even, in varying degree, the teachers of religion with their rituals and incantations, cast an aura of mysticism and wonderment over their respective works. It is not my purpose to examine the merits of this ancient practice as applied to the specialized fields I have mentioned, but rather to assert, dogmatically if you please, that it cannot and must not be applied to the fields of business and economics. As a matter of fact our economists have not needed a special vocabulary of occult terms because even when they use plain English the general public finds itself not infrequently in the position of the chap who after listening to his economist friend for half an hour said, "I understood every word you said, but not a single sentence!" Nor is this to cast reflection on economists. They are a great and intrepid group, engaged in analyzing an immense, living, shifting, many-sided and highly psychic body, the components of which are continually changing in size and perhaps in function, with the result that detailed study of the individual parts, as in surgery, chemistry or engineering, is difficult and of relative value only. But the study goes forward apace, relative values are being assigned, the psychological aspects weighed and in the end we may, I believe, reasonably hope for broad acceptance and agreement by economists on those fundamental principles and factors, whatever they may be, that are necessary to the preservation of our American way of life.

In the meantime we all who are a part of the business and industrial life of this country must continually remember that ignorance on the part of the American people of what private business is and how it functions is the greatest single threat to national progress. We must not be reticent to tell the truthful story of our work in terms which all can understand.

We have heard a great deal in the past decade about free enterprise and the capitalistic system versus, on the one hand, state socialism, with its government ownership and operation of all productive facilities, and, on the other hand, the authoritarian state wherein private ownership continues but is subject to the control of a dictator and his party. In Europe we have seen living examples of the two last mentioned forms of government, beginning, as they did, with principles and programs diametrically not to say rancorously opposed, and reaching in the end such shocking identity of policy, technique and performance that they find themselves in what has been described as an obscene embrace.

In a truly socialistic state there can be of course no capitalism or free enterprise as we understand it. In a state ruled by a dictator, private enterprise may theoretically and to some extent actually exist, but the very presence of dictatorial power to regulate men's private affairs and direct their business activities, however well intentioned the dictator and however benignly that power may be used, is a serious and crippling deterrent to long range planning by private business, to the pioneering of new industries and the taking of long finan-

cial risks in the hope of reaping large rewards.

So we arrive almost at the outset at the conclusion that the capitalistic system (if it is worth preserving, and I shall say more about that in a moment) can best function in a democratic state where the broad rules for living have been laid down by the people themselves in a fundamental document, where the more specific rules within the broad framework are made from time to time as need arises by chosen representatives of the people, acting for a limited time only, and where the administrative officers of the government, also chosen by the people for a limited time, have only such authority and discretionary power as enables them adequately to carry out and effectuate the rules so laid down.

Democracy Does Not Guarantee Enterprise System

But it will be noted at once that while this democratic state may under proper circumstances provide natural, healthy surroundings for the enterprise system, it may equally be applied to a partially socialized economy. In other words, the broad concept of government of the people, by the people and for the people, though it definitely excludes the notion of rule by despot or by dictator, contains no inherent guarantee of the private enterprise system as we know it here and no inhibitions against government activity in business, agriculture or any other field. Whether it shall be the one or the other or a combination of both, and whether having tried one for 150 years the other shall be experimented with for a time, is for the people to decide.

I make this observation, well known as it is to you all, simply by way of reminder that in theory at least private enterprise is not necessary to the existence of a democracy, and for that reason it must be understood and wanted for itself, quite apart from democracy as such, if we are to avoid the socialization of American industry, slowly, gradually at first, but of necessity with increasing rapidity.

Now what is this thing we call capitalism or the enterprise system; what has it done for us and is it worth preserving? The enterprise system has been defined as the system of private property and the profit motive; but like many definitions, this one says so much in so few words that one learns little from it. Also, our real interest lies less in what the system is than in what it does for us, what it accomplishes in terms of everyday living.

Basically of course the enterprise system provides *opportunity* and *incentive* for people to improve their condition in life. This is so because under it we may own and hold the fruits of our labor, and any man therefore who can devise a product or can perform a service which because of its price, its quality or its originality is more desirable to his fellows than other available products or services, will prosper and enlarge his savings so long as he can hold this advantageous position. But those who seek also to sell *their* products or services are constantly and eternally at work to make them better, cheaper and more useful so that they in turn may assume leadership in the field and enjoy the reward of customer acceptance and demand. And if we multiply this situation many thousands of times and apply it to all the fields of productive endeavor, we find that we have put into motion a cosmic mechanism for the production of continuously better, cheaper and more useful things of life, with the inevitable accompaniment of a rising standard of living, and we have motivated the mechanism with that elemental fuel—the human urge to achieve a better and more comfortable position in life.

Socialism Has Not Succeeded

Compare this self-starting and self-operating mechanism with any scheme of things in which the elements of private ownership and the profit motive are absent. However one may theorize on the idealistic beauty of the socialized community in which all property is the property of all and all endeavor is for the benefit of all, the fact remains that although a number of sincere attempts have been made to function on this communal basis, none has yet succeeded. And I suspect that so long as we humans are what we are, none ever will. For without the profit motive, without the opportunity and incentive to obtain personal advantage by hard work and careful planning, a very high percentage of us humans just wouldn't get around to doing it.

But we need not deal with such extreme examples as the theoretical socialized community in order to compare the results of production and service activity with and without private ownership and the profit motive. Foreign government ownership and operation of such public utilities as the telephone, gas, electricity and radio-broadcasting industries affords more than adequate demonstration. Again and again we have seen that even in capable and public-spirited hands, the public must sooner or later (and generally sooner) suffer from government ownership's inefficiency, inertia and complete lack of the profit motive's driving urge to find better and cheaper ways to do the job and to enlarge the service. And this is no reflection on the operators of government-owned business; it is simply proof of our fundamental thesis that man, whether he be a government official or a private citizen, will not over a period of time perform business functions as efficiently or as progressively under a system which does not give him freedom of action and a personal stake in the results.

Free Enterprise System Benefits the Employee

And right here let me interject that too many people are under the mistaken impression that the profit motive is something that applies only to and is for the exclusive benefit of employers, investors and owners of business institutions. Nothing could be farther from the truth. The profit motive as a part of our free enterprise system directly affects and provides personal opportunity for every employee and worker in private enterprise in this country. The constant pressure inherent in the system to produce better and cheaper goods puts each employee and his personal efficiency and performance under the scrutiny of those who direct and supervise the work.

In many companies every factory job or task is evaluated in relation to all others so that the compensation for each has a direct and appropriate relationship to the training and skill required to perform it. And having rated or evaluated a job, the compensation for that job is not one fixed figure but is variable within prescribed limits and every employee performing a given task is rated and paid on the basis of his own ability and efficiency in performing that task. An enterprising employee, therefore, seeking greater profit from his employment may increase his compensation on a given job by performing it better than his neighbor and can move on to other and higher rated jobs by studying and preparing himself to perform them.

This is simply one example of many that might be given to demonstrate that free enterprise and the profit motive reward individual initiative and ability, whether it be found in the sagacity of one who provides capital for new enterprise, or the planning judgment of a manager, or the skill and resourcefulness of a man in the shop.

And what, may one ask, makes possible on the one hand and motivates on the other, the unionization of American workers? The answer is free enterprise and the profit motive as applied to labor. Unions as we know them here are nonexistent in countries where communism and dictatorship flourish and where free enterprise is gone or going. But here, where men are not told by their government what work they shall do and at what pay, where freedom of action still exists, they are free to leave one job if they can find a better one, they are free to join an outside union or to organize their own or to deal directly and individually with their boss. And the decision, quite naturally, is reached on what in their judgment will be best for them individually—the profit motive again at work.

So when we come across the terms free enterprise, capitalism and the profit motive, let us think of their true significance, which is freedom of action and individual opportunity to improve one's position in life by hard work and careful planning. And let us remember that this freedom and this opportunity is for every citizen in the land.

And if under this system there are sometimes more men than jobs and at other times more jobs than men, and even if we assume that some part of this fluctuation is perhaps inherent in the free enterprise system and not chargeable to unfriendly attitudes or policies of government, we still find, in my humble judgment, the scales of national self interest heavily balanced in favor of free enterprise as against government regimentation and the sacrifice of individual opportunity.

Lord Chesterfield once said that a despotism, with which I include dictatorism, may almost be defined as a tired democracy. And may it not truly be said that for a people to permit its government, not merely to regulate, but to control and compete with its private business enterprises, is also evidence of a tired and misguided democracy?

This is not to say of course that government shall not engage in any business. There are some in which it alone can properly engage despite its inherent handicaps, and there are others in which it must engage directly or through subsidy for the very reason that private industry under the compelling influence of the profit motive is unwilling to hazard its capital. But the test, the all important test to be applied to each proposal that government enter the natural and traditional field of private business, is this: Can the job be done or is it being done with private capital and under the profit motive system? If so, I submit that every American should insist upon doing it that way because, and only because, it surely will be done better and at less expense. If, on the other hand, private capital cannot be interested in the project, we may fairly assume that it is a hazardous one from the standpoint of the investor and that if government be the investor it may be expected to sustain heavy losses. On this realistic basis, then, we may evaluate the desirability of the project and the need of proceeding with it in the public interest.

Competition Is a Vital part of the Enterprise System

Although it is implicit in much that I have said about the enterprise system, I have up to this point laid particular stress on the profit motive rather than on competition. I did this for the reason that the profit motive is the ever present common denominator of all private business, whereas competition varies greatly in degree as between such industries as the telephone or light and power industries on the one hand, which are inherently unsuited to competition and whose rates are fixed by Government Commissions, and on the other hand such industries, for example, as the steel, automotive and electrical manufacturing industries, which are suited for and do have wide competitive activity. But regardless of these inherent differences, a word about competition in its broader aspects may not be inappropriate.

It is generally assumed that competition is the purchaser's protection against excessive prices and that the purchaser (or the general public) is the principal, if not the sole, beneficiary. To be sure, competition does serve this purpose; sometimes, indeed, not wisely but too well! And while I sincerely believe that American business has learned a great deal in recent years about price economics and that the day of the big-time profiteer is gone, yet I would be the last willingly to relinquish competition. It is an integral and vital part of this enterprise system of ours under which millions of minds are constantly searching for new products and new ways to make old products better and cheaper, and for better and cheaper ways to distribute them. It is a race, reckless at times, and always breathless, but it is good. I have seen so often the stimulating and vitalizing effect in my own company of a new development by a competitor, and the manner in which a tight competitive situation will banish complacency and produce answers to problems theretofore considered unanswerable.

The old cliché, "Necessity is the mother of invention," is still heavy with truth. Whatever General Electric may have been able to do by way of stimulating its 1500 or 1600 competitors in the electrical manufacturing industry, it hereby acknowledges with sincere thanks the stimulation it has received from them these many years.

And so, while I am quick to acknowledge the benefits of competition in and between business, it must be remembered that competition can also be a destructive and highly antisocial instrument. Too much of it results in whole industries operating at a loss with consequent gradual dissipation of the invested capital of the industry, financial inability to carry on adequate development and research programs, and, with the elimination through bankruptcy of the weakest and then the intermediate units, the ultimate creation of a monopoly in the survivors which defeats the very purpose of the competitive system. And while cases may be found of industries which have operated at a loss for extended periods without substantially reducing the number of competitors, this can happen only so long as new capital is available to refinance the weaker units or to purchase at bargain prices the plant and equipment of bankrupt companies. And no one would seriously contend that the public is or can be well served by an industry that is distributing part of its capital with every sale and that has no funds to finance forward programs of product and equipment improvement, which over a period of years would permit profitable price reductions below the present unprofitable selling prices.

What we really seek therefore is that degree of competition which will continuously keep business management under urgent pressure to move forward in the direction of better and cheaper products, and which will promptly penalize through diminishing profits the concern which fails to make its contribution or keep abreast of progress day after day and year after year. Having created this condition, competition has fully served its purpose, and to do more than that is to defeat its own end and weaken the national economy. Because this is so and because conditions are not the same in any two industries, an attempt to impose one legislative rule of thumb on competition in all industries must necessarily prove in large part abortive. Better no doubt than nothing are our Federal anti-

trust laws, but blanketing, as their vaguely worded provisions do, so many fields of legitimate and sound economic cooperation, the problem of enforcing these statutes becomes almost as difficult as that of understanding and complying with them.

But the solution, let me hasten to say, is not a simple one. To serve best the national interest, antitrust laws must of necessity be flexible so that the particular and varied problems of each industry within their compass can be met and dealt with individually to the end that such degree of competition shall exist as truly serves and protects the consumer. To effectuate this program would doubtless require an underlying broad prohibition against clearly defined restraints of trade, with provisions for the exemption, subject to periodic review, of any industry voluntarily presenting a plan for industry cooperation which is demonstrably in the national interest and is approved by a government body familiar with the conditions in that field.

Free Enterprise System Is Fundamentally Sound

But this is not the time or the place to discuss revision of our antitrust laws. We had been talking of competition which, with private ownership and the profit motive, constitute the main spring, the self-operating unwind-downable main spring of our American free enterprise system. And the conclusion seems clear that whatever the failures in our economic scheme of things, however great the problems of unemployment, economic inequality and the current hesitation of private capital to flow freely into new and expanding enterprises, the fault cannot and does not lie in the foundation of our economic system, which is free enterprise, and which functions and will function just as surely as human beings are born with an urge to improve their lot. The trouble, I submit, lies in the design and operation of the structure we erected on that firm foundation. If we can simplify our search to this extent and concentrate our energies on finding the architectural and administrative faults in our economic building rather than in its foundation, we shall have accomplished much.

Business Must Tell Its Story to the American People

American business is now, I think, awake to the need of telling this story to the American people. We too long assumed that the enterprise system was a permanent and impregnable part of the American scene, and we awoke one day to find an astonishingly large number of our fellow Americans who do not understand it and who have come to regard American business with doubt and with suspicion, natural enough no doubt when one considers the ten years of depression we have just been through and the millions of young people who have reached working age, with no work to do, during that period. We can, I submit, devote time and careful attention no better than to the understanding and education of these many Americans.

And in the meantime, entering as we are an unpredictable period in a torn and troubled world, with a strong likelihood of quick and important changes in the business outlook almost from day to day, what can we do better to prepare ourselves for rapid adjustment to the shifting times?

You may recall the youngster who, when asked to define an adult, said that an adult is a person who has stopped growing except in the middle. While Webster is much kinder in his definition, there is something both interesting and arresting in the child's definition as applied to corporate organizations which have reached maturity. It is too often the case with these companies that while at one end direct labor and raw material may be utilized well and efficiently, and while at the other end of the organization there may be no increase in management personnel or expense, the middle section where lies the great bulk of general expense and overhead, shows an unhealthy bulge. I make no suggestion that this is true of your companies, gentlemen, and I mention it simply as a prelude to the very general and much safer observation that the best preparation I can imagine for the part business must play in the economic rough-and-tumble that may lie ahead, is a good look at itself in the mirror, and a course of diet and training to remove anything not functionally essential; in a word, to restore the corporate figure and to put tone and vitality into every part.

I do not look into the future with trepidation. Quite the contrary. I firmly believe that the present trend of national feeling is away from the something-for-nothing school of thought, away from the past willingness to experiment here, there and everywhere, and definitely in the direction of the more realistic point of view which recognizes that money as such contains no vitamins, is useless for shelter or for clothing, and is no more than a convenient substitute for the direct exchange of the products of industry or agriculture which, rather than money, represents the wealth of a people; and that accordingly unless business deterrents are removed and the American people turn confidently and eagerly to the task of making ever better, ever cheaper goods for more people to buy, there can be no permanent answer to unemployment and social security.

And while I am confident of these things, I recognize, too, that we are not the masters of our fate, that we face many questions, world-wide questions, which today are imponderable and over which we have little control. And so I say, let us do what we can to be ready. Let us tell the story of free enterprise anywhere and everywhere we can, and let us oppose every project or program that will weaken or destroy it. Let us make our business institutions keen, lithe and vigorous, for with efficient and functional productive organizations we can at least start quickly and change quickly. We cannot be certain of the future, but we can face it with confidence and high courage. For, as Oliver Wendell Holmes once said, "The longing for certainty and repose is in every human mind. But certainty is generally illusion and repose is not the destiny of man."

Winners in MKB's Newspaper Advertising Contest

THE Modern Kitchen Bureau's contest for the best series of newspaper advertising on electric water heating has been won by: T. H. KETTLE, Advertising Manager, Northern States Power Company, Minneapolis, Minn.

Second prize goes to: JOHN G. LONGSDORF, Advertising Manager, Indianapolis Power & Light Company, Indianapolis, Ind.

Third prize: FENTRESS TUCKER, Municipal Power & Light Plant, Richmond, Ind.

The awards carry cash prizes of $250, $100, and $50 respectively.

The Northern States Power Company advertising, which won first honors, emphasized the convenient *help* that an electric water heater brings to the home. The series ran during February and March. H. G. Huey, Merchandise Manager of the Company, declares: "Our electric water heater business is holding up very nicely and showing a very satisfactory increase. We attribute no small part of it to this very effective series of advertisements."

The Indianapolis advertisements were illustrated effectively by pictures of babies, each of whom expressed his own ideas very emphatically as to the need of hot water in the home.

The Richmond series stressed *use*, pointing out the number of times the head of the household would need hot water for shaving in the years to come, or the number of times the housewife would need it the rest of her life for washing dishes or clothes.

Judges of the contest were J. E. D. Coffey, of *Retail Ledger*, New York, N. Y., Howard W. Dickinson, Committee on Consumer Relations in Advertising, New York, N. Y., and Herbert L. Stephen, *Printers' Ink*, New York, N. Y.

The American Way of Work

By Ralph Kelly

Vice-President, Westinghouse Electric and Manufacturing Company

Address before the Third General Session of the Eighth Annual Convention of the Edison Electric Institute, Atlantic City, N. J., June 5, 1940

IN talking of "The American Way of Work" before this group I feel myself in the hands of friends, because my company is definitely a part of our great electrical industry, an industry which a year ago at your meeting in New York, Mr. Floyd L. Carlisle said "was built up by men of great inventive genius, courage, flexibility, capacity to meet and adapt progressive changes—salesmen of service."

The electrical manufacturers and the utility operators have sailed on many an uncharted sea together. When we have felt we were ready to take the risk of building something entirely new, we have always found a utility operator who was willing to share the risk with us and try it out. Our accomplishments as a manufacturer have been part of the accomplishments of the whole industry.

A leading editorialist advocated the compiling of a written history of our accomplishments, which, in turn, would give a history of our industry. If any of you attempted to keep a list of these achievements for any considerable time, as I did, you would discover that, so swiftly do we progress, the objectives achieved, begin to grow obsolete before the record leaves the printer's hands.

For instance, let us glance at a few of the things which have transpired since we met together a year ago at the World's Fair in New York. Quite naturally I turn to the laboratories and works of my own company for examples, but these are only typical of what companies such as ours have been doing.

In our exhibits at both the New York and San Francisco Fairs we endeavored to show how the electrical industry improves the comfort, convenience and manner of living of our whole people. At our exhibit in New York we buried our famous "Time Capsule." Here was to be a picture of our civilization enshrined for generations five thousand years hence. We were sure the "Time Capsule" would last five thousand years because its outer shell was made of a new alloy—Cupaloy. This metal came from our research laboratories and has remarkable

MR. KELLY

permanent physical properties. Our capsule was scarcely in the ground when our research laboratory announced a new metal quite superior to Cupaloy. This was named Cuferco.

They had not perfected Cuferco when another metal of the same type was developed—a special alloy stronger than certain steels and which retains its strength up to temperatures beyond 2000 deg. F. Even the research scientists gave up trying to find a descriptive name for this child of their furnaces. They simply spoke of the new metal as K-42-B.

All this may seem a long way from the business of manufacturing motors, turbines, switches, lamps and things normally associated with our company; but it is this continuing program of research that forms the foundation for the electrical industry.

An example of continuing research is that of the development of electrical steel. Some people think that this development stopped when silicon steel was introduced into transformers. Yet, this year when the airplane industry said they must reduce the weight of their auxiliaries, we produced a steel for them having a magnetic strength per pound many times that of steel normally used in such applications.

These same research men talked us into a substantial investment in an atom smasher. We excused ourselves for this seeming extravagance by saying, "We must encourage fundamental research," —particularly we in the sales department who couldn't see any market for the sale of broken-up atoms.

Then one day they told us that the atom smasher may be the means of producing at a very low cost, radio-active materials which would compete with radium. One particularly fascinating aspect of this work is its potential benefit to so-called "tracer" medicine. If a radio-active medicine is administered to the human system, its progress through the system can be determined by a simple device that measures radio-activity.

In the atom smasher we have taken a dense black carbon, graphite, and from it produced radio-active nitrogen, a colorless gas. The nitrogen retained its radio-active properties for a time; then, as it lost them, reverted to graphite. This is just the beginning of useful knowledge to be obtained from this corridor into fundamental research.

Other research developments have taken unexpected turns. Many of you are familiar with our experiments of a few years ago in the development of an improved air filter, The Precipitron.

The Precipitron is an electrical sieve through which gases like oxygen, nitrogen, CO_2—the gases of air—pass freely but where solid particles are trapped. There are many mechanical filters that do an excellent job of straining out the big particles from the air, but really small particles slip through as easily as a penny through a sidewalk grating, and for the same reason. The Precipitron gets them all, regardless of size. Bacteria, smoke particles, silica dust, even pollen—of which some of you may be painfully aware every fall—are caught by this master trapper.

At first we thought that the Precipitron was too complicated for commercial exploitation and used it only as a part of

our traveling research show. Then some doctors thought it would help certain types of hay fever and asthma, and this was found to be true. Some large stores discovered that its use would save thousands of dollars by keeping dust off their counters and goods. Power plants are making installations to keep dirt out of the insulation of generating equipment.

What started out as a laboratory experiment is this year beginning to rival our air-conditioning department as a business and as a load builder for the utilities.

One of the fundamentals of the industrial age is that the products of inventive genius, while saving labor, actually create more jobs. Seldom does a new product spell doom to its predecessors. It simply creates a new demand or enlarges an old one. The continuing parade of new lamps marching out of the lamp laboratories clearly supports this fact.

Let's consider the new fluorescent lamps by which large quantities of white and colored lights can be obtained efficiently. These amazing lamps don't have filaments as in ordinary Mazda lamps. The electric current simply passes through a mercury gas in the tube. The radiation in this gas is transformed by special coating on the inside walls of the tube very efficiently into light.

How these lamps give more light for less current and yet act as load builders is a little obscure at first glance. But in practice, the effect is two-fold. Their use makes people more light-conscious, raises the accepted standard for foot-candles of illumination and promotes higher standards of lighting in offices and factories. It brings within the bounds of economic feasibility more combination lighting and air conditioning loads which might not otherwise be considered.

A classic example of the benefits that can extend from a single development is that of the Sterilamp—a development of our lamp laboratory. In the hands of the medical profession this lamp is carrying on the fight for asepsis in surgery which was started by Pasteur and Lister.

Lister realized that the air in an operating room was a carrier of germs of infection. He tried to combat this by a spray of carbolic acid in the air, but was unsuccessful. Other great surgeons striving for perfection in their technique tried various methods of eliminating air-borne bacteria as a cause of infection in operations. None of these was successful and with every precaution a certain percentage of wounds in very complicated operations became infected. The reason was known to be air-borne bacteria, but no one could do anything about it.

Then came the Sterilamp. It kills bacteria organisms exposed to its rays. Used in the battery of lights over an operating table, it kills all the germs in the air over the operation.

In a recent medical article Dr. Hart of Duke University says that in a study of some two thousand complicated operations where the Sterilamp was used, the incidence of infection was reduced to one per cent. Without the Sterilamp, the expected incidence of infection in operations of a similar type would have been 10 per cent.

However, as a load builder, you will be interested in the progress of the Sterilamp as applied to the Tenderay process of aging beef. With this process meat can be properly aged in 72 hours instead of six to eight weeks. This permits the packer to merchandise a specific brand of beef of uniform tenderness at less cost. It permits the housewife to serve steaks, bought from the average butcher shop at average price, which have a tenderness and palatability usually associated with expensive choice cuts. Who would have ventured to forecast, even ten years ago, a connection between the lamp laboratory and your tonight's beefsteak?

Let us leave the indoor laboratories for a few moments and go to the outdoors. The approach to the study of that arch-enemy lightning is one of the most interesting of our time. Lightning means power outages, apparatus failures, unless we can protect against it.

Twenty years ago we built a device that would measure lightning. If you can measure a destructive force, you can usually reproduce it in the laboratory and find a cure. This early instrument gave us part of the story, but not all of it. Each year we made improvements, until a little more than a year ago we completed the development of a device which would measure lightning far more completely than ever. We call it the Fulchronograph.

About fifty of these devices have been installed around the country. They were placed on high buildings, high mountains, transmission towers and all sorts of exposed places. Then we prayed for them to get struck by lightning and in some cases our prayers were answered. We measured one stroke of most unusual magnitude on the top of the 42-story Cathedral of Learning at the University of Pittsburgh.

What does all this mean to you and to us? It enables us to build lightning generators which we know are duplicating natural lightning. We can thus test our equipment for protection from lightning under the service conditions of the field. Apparatus shipped from our factories will give a much better account of itself. You will have improved reliability of service to your customers. These are only a few of the results that will be obtained from this increased knowledge of lightning.

Our business is exceedingly fascinating because it has so many widely differing problems. One of you gentlemen may come to us today and ask us to build the largest generator ever built. Tomorrow you may need a delicate instrument motivated by the tiniest motor. You gave us a problem of eliminating radio interference from your distribution lines. That gave us a problem in insulator design which was solved by a radio interference-proof insulator.

You wanted circuit breakers for your power stations which would have no oil in them. There was no reflection on oil circuit breakers, which are among our most reliable pieces of equipment. You wished to give your stations the additional protection from fire which you felt the removal of oil would bring.

Air blast breakers have been used in Europe for a number of years. However, since European systems are not as large as ours, the interrupting duty of their breakers is only about one-third of what we need over here. It was up to us to do a better job for American conditions. We have done this and have produced an air blast breaker that will interrupt a million and a half kva.

Of course we are happy that our company and similar great engineering companies can do a job like this. But what should make us most happy is that these advances are the result of individual private enterprise. They come from the American Way of Work.

I mentioned earlier how closely related are our problems as manufacturers and yours as operators of public utilities. During this past year we had one of the clearest examples of that which has occurred in a number of years. I refer to the experience with topping turbines.

Topping turbines form only a small part of our total turbine business, but they are a most important part. No development in central station history of recent years has increased power-house efficiency like the topping turbine. Some-

(*Continued on page* 376)

More and More for Less and Less

By H. L. Wallau

Chief Executive Electrical Engineer, The Cleveland Electric Illuminating Company

Address Before the Third Session of the Eighth Annual Convention of the Edison Electric Institute, Atlantic City, N. J., June 5, 1940

DESPITE the effects of the economic crisis which marked the beginning of the decade just ended, electrical energy has continued to become more closely associated with every phase of human activity in these United States. Old applications have been improved, new applications have been developed, the most humble as well as the most powerful have been benefited thereby. True, at first ground was lost. But the recession permitted our industry to review its situation, plan new ways of regaining lost business, and now the losses have been offset and further gains achieved. The economic value of the domestic and small commercial consumer was emphatically manifested during these years and but for the buoyancy of these classes of load our industry might well have been swamped and no life lines would have been cast to it by the captains of our State.

The decreasing revenues which began to be manifest in the early thirties, coupled with subsequent pressure for lower rates and ever mounting taxes, made it imperative that every avenue of decreasing the delivered cost of both kilowatts and kilowatthours to our consumers be explored thoroughly and advantage taken of all possible means. This led to many studies as to ways of reducing investment, improving efficiencies and lowering maintenance expense. The greatest immediate gains were in the reduction of the costs of generation. These have progressed to a point beyond which, in general, future gains will become increasingly difficult. Possibilities may be offered by the gas turbine, the development of which is progressing steadily, but its application to large generator units is still in the future.

The studies, some of which are still being pursued, included determining the permissible overloads which might be carried on equipment and circuits in order that the margins of reserve heretofore deemed obligatory might be reduced without sacrifice of dependability. Interconnections, to take advantage of more

MR. WALLAU

efficient generation, of decreased generating equipment reserve requirements for an interconnected group of properties, of the maximum efficient use of hydro-facilities and of the diversity between large areas, were carefully analyzed and where economically feasible, made effective. Today the interconnected operation of systems totaling several million kilowatts of load is commonplace. Economic advances have been made in all parts of our systems from coal pile to consumer's load. Simultaneously, means of improving service continuity and voltage regulation were studied. Developments in transformers, lightning arresters and protective relaying have been marked, circuit breakers have been greatly improved as to interrupting ability and speed of operation, and apparatus all along the line in general made more rugged and reliable and of improved efficiency. The use of fast relaying and rapid circuit breaker reclosure has greatly increased the dependability of transmission and distribution with consequent reduction in stand-by circuits required. So we may well briefly pause to review somewhat more specifically some of the developments which the decade has brought forth and, if possible, evaluate future trends.

Production

It is not in my province to go into detail as to improvements in production. Thanks to the efforts of research workers, chemists and metallurgists, the use and reliability of high-pressure, high-temperature steam production and utilization equipment has continued to increase, resulting in a continually decreasing fuel consumption per unit of output. Twelve hundred pound equipment already was available ten years ago; in 1937, a 2300 lb, 940 deg F, 22,500 kw unit was ordered for the Twin Branch Plant of the Indiana and Michigan Electric Co. By such bold ventures is progress recorded in the Annals of Time. Many plants have been modernized by the use of such equipment in the form of topping units. The first large scale application of this principle of operation was made about thirty years ago in the power plant of The Interborough Rapid Transit Company in New York City. Here the application of the turbines was reversed, being applied on the low pressure side of the reciprocating engines.

Increased production capacity may be obtained from plants at new locations or by additions to existing plants. The latter often have limitations in land area and condensing water facilities or both which may preclude the installation of condensing turbines and so make modernization by superpositioning increasingly attractive. The incremental cost of such new capacity is relatively low, overall station thermal efficiency is increased, giving the old development a new lease on life. Furthermore, these enlarged and modernized plants are located on sites previously selected because of their favorable location with regard to the system load and from which transmission facilities for the added capacities are either available or may be installed at lower costs than those involved in totally new developments. During periods when the flow of investment capital is decidely sluggish, this is no mean advantage.

Generators

The developments in turbine generators have been chiefly in refinements and

details, and in the progressively improved designs and manufacture of large 3600 rpm units. The advent of hydrogen cooling, which was first applied to synchronous condensers and frequency changers, has been a factor in reducing windage losses and correspondingly improving their overall efficiency. It is thought that the hydrogen atmosphere will increase the life of machine insulation. In the hydro-field, probably the greatest advance has been the increasing use, since the Safe Harbor installation in 1931, of large automatically adjustable blade propeller wheels of the Kaplan and other types, which yield a much flatter efficiency curve over the usual range of loading of from 30 to 100 per cent, with a practically constant water rate between approximately 50 and 80 per cent of rating.

Ten years ago, installations of steam-driven units as large as 208,000 kw in the cross-compound type, 160,000 kw in the tandem-compound type, and 110,000 kw in vertical-compound types were made. Single cylinder units of 100,000 kva were available. These units still rank among our largest. In 1935 a 165,000 kw single shaft unit was installed in Philadelphia. The average size of new units installed has generally increased as systems expanded. A similar situation exists in the hydro-field. Federal activity in the development of water power sites led to the production of units of 82,500 hp for Boulder Dam, some 6 per cent larger than the 77,500 hp units manufactured ten years ago for the Dnieper River development in Russia.

Station Auxiliary Supply

In a hydro plant the problem of securing a reliable supply of auxiliary power can usually be solved in a very simple manner. In a steam plant, the great number of essential auxiliaries calls for a most painstaking design to insure utmost reliability. In new installations these requirements have been steadfastly borne in mind and in many existing plants the power supply to auxiliaries has been revamped and modernized to afford as nearly as economically possible, reliability of the highest order.

Electrical Station Modernization

Several major shutdowns of larger systems brought to the forefront for executives and engineers alike links of the systems which might develop weaknesses, resulting in major electrical modernization and reconstruction of switch houses, breaker equipment, busses and connections. The keynote of design has been economy with safety coupled with simplification and isolation, both physical and electrical, to minimize the possibility of fault occurrence, and to confine the deleterious effects which might result from a fault, to a very minimum of physical space, so as to involve as little equipment as possible. This has called for better bus sectionalization, improved relaying (particularly as to speed of clearing faults) breaker modernization, and in some cases, the limitation of fault currents by reactors to values, which the breakers immediately concerned in clearing them can safely handle. It has also led to an increased use of physical barriers between independent pieces of electrical equipment as well as groups of associated equipment. At least one switch house and several transmission substations recently built have used metal-clad switchgear, in which all pieces of equipment are placed in separate metal compartments entirely closed off from one another and inaccessible to operators and maintenance men, until certain safety precautions have been taken.

Safety is increased by the use of interconnected manual or by electrical interlocks or combinations of both. Safety of personnel is ever before the minds of our designers and operators, and continuous study has led to the reduction of hazards in all parts of our systems. Much thought has been given to providing more adequate means of fighting fires should they develop, and improved systems using water, carbon dioxide or other chemical extinguishing agents have been installed in existing and new power plants and substations. The general trend favors the use of permanently piped automatic water systems for outdoor equipment and carbon dioxide (or other chemical extinguishers) for indoor equipment, but water systems of the fogging spray type are also gaining favor for indoor use.

Transmission

Impetus was given high voltage underground transmission in 1924 by its successful installation in Cleveland at 66 kv. Since generally overhead lines of this and higher voltages would not be permitted on city streets and the costs of private urban rights-of-way for them prohibitive, underground transmission of bulk power in or out of metropolitan areas has been largely resorted to at voltages as high as 132 kv here (220 kv abroad) with concomitant economic benefits. The mileage of the high voltage overhead transmission has been markedly increased; the 270-mile double circuit. 287.5 kv line between Boulder Dam and Los Angeles with a power limit of the order of 265,000 kw per circuit is the ultimate so far achieved. A development such as this, of the reliability required for a project of such magnitude, would have been impossible without the parallel progress that came about in the fields of natural lightning research, circuit interrupting devices and relaying. In the latter field, the use of carrier current permits types of relaying to be used over long distances which, if separate auxiliary pilot channels were required, would be justifiable economically in extreme cases only, if at all.

In addition to relaying, both pilot wire and carrier current circuits have been developed to a high degree for the supervisory control of station and substation equipment and for the telemetering of loads, water levels and other quantities of importance to system dispatchers. Very accurate metering devices have been produced for automatic load and frequency control in power plants and over tie lines. Increased stability has been gained through their use. Large transformers having both automatic voltage and phase shift control have been used to close high tension loop circuits, eliminating circulating currents and permitting load transfers in either direction at the transformer within the capacity of the apparatus.

All of these developments in transmission and control give today's designer far greater latitude in the choice of locations for power plant and substation sites; permit of striking more favorable economic balances for project additions, and result in greater flexibility and more economical operation when applied to existing installations.

Substations

In substation design, too, emphasis has been placed upon simplification, reliability and economy. In many cases the high tension supply lines and their associated step-down equipments are designed of equal capacity and the connection between the two is made without the intervention of circuit breakers and associated equipment. This not only reduces investment but decreases maintenance expense as well, and for each piece of equipment eliminated, one potential source of hazard is eliminated.

In sparsely settled territory substation transformers may be connected through fuses to transmission circuits supplying

several load centers in order to eliminate costly breakers. More and more equipment has been placed outdoors, transformers, breakers, synchronous condensers, regulators, thereby reducing building space and cost and relieving the congestion of equipment often inherent in earlier designs. Metal enclosed switchgear has been further developed and this type of construction in various forms is becoming increasingly favored. A very recent tendency is toward the use of air breakers in distribution substations of the less than 5000 volt class. A growing realization of the value of liberal spacing for outdoor equipment, coupled when advisable with the use of barrier walls or cells between equipment units and of adequate fire protection, is manifest.

Present developments in breakers include air breakers in the 15 kv class being offered by all the principal manufacturers, and still higher voltage classes will presumably be made available later. This may check the tendency to develop outdoor switch yards in order to place oil-filled breaker equipment in the open and further stimulate the use of metal-clad gear, air breaker equipped, in switch houses, in generating stations and substations, especially in metropolitan areas in which large tracts of land are not only expensive but often not obtainable unless relatively very costly improved property is purchased. Oil maintenance and oil fire risk will be reduced by such construction. Indoor installation eliminates the maintenance problems caused by exposure to the elements, permits the use of less expensive types of breaker bushings and has advantages in the form of compactness and ready accessibility in inclement weather.

Distribution

The use of reclosing circuit breakers for the purpose of reducing the duration of interruptions has grown and is not only applied to overhead distribution circuits but frequently to high voltage transmission lines, so that circuits on which self-clearing faults have developed will be restored in a few cycles without interrupting the motor load on the line and without adjacent load centers falling out of step.

As a result of the increasing demand for service extensions into sparsely settled rural territory, the industry has made great strides in developing low cost methods of serving this type of business in order that the investment required might be more commensurate with its low revenue yield. Many thousands of miles of rural line have been built. It is not unreasonable to hope that eventually as the occupants of the farms now supplied become more and more aware of the convenience and low cost of electric service, their usage of current will increase and, as a class, they will develop into profitable customers. But before this generally comes about, the cash position of the farmer must be bettered.

In urban distribution, the low voltage a-c network has made marked advances. It is being installed not only in smaller communities in which comparatively heavy load concentrations are beginning to be manifest, but in metropolitan centers where it is supplementing d-c networks in fringe territory or actually infiltrating in established d-c districts and, in some cases, supplanting the d-c altogether. A-c networks may readily be supplied at subtransmission voltages directly from generating plants or from transmission substations. When so designed, distribution substations are eliminated. A design limitation in maximum loading must be observed, dependent upon the system capacities available, in order that in case of complete shutdown, the individual networks of a system may be successfully re-energized without crippling their sources of supply. The parallel operation of their low voltage transformers results in a stiff voltage grid, generally immune to objectionable dips when heavy consumer equipment is suddenly energized.

Another trend in urban distribution is the decentralization of substations. Engineers are using more baskets and placing fewer eggs in each. These substations may take a very simple form, being relatively low cost equipment in weatherproof housings consisting of one or two moderate sized transformers, usually with load tap changing equipment for voltage regulation and a limited number of feeder positions. No building is required for their installation and when system growth makes a change in the type of local distribution advisable, they may be disconnected, removed as units and installed elsewhere at small cost. Where this type of substation has been properly located, upon removal, its supply circuits will fit the transmission requirements necessitated by the changes to be effected in local distribution in a very satisfactory manner.

Mobile substations for emergency or temporary use have been developed, decreasing the time to restore or furnish service, permitting permanent work to be done more conveniently. Improvements have also been made in distribution equipment of all kinds, new methods of customer service entrances for small installations have been worked out, a material reduction in the number of ratings of meters required has been accomplished with a gratifying decrease in meter costs. The new meter sequence is now generally used and outdoor metering to reduce current diversion and to eliminate the necessity of duplicate trips for meter reading purposes is fast gaining favor except for the large consumers.

Utilization

The load building activities of utility sales departments have resulted in adding a considerable wattage in lighting load among all classes of consumers and their efforts have been marked with great success in the residential field through the practically continuous "Better Light-Better Sight" campaigns that have prevailed during these past years. Improvements and price reductions in other domestic equipment such as refrigerators, ranges and water heaters, together with rates adapted to promote their use, have resulted in a considerable increase in energy consumption. Joint industry committee efforts produced improvements in design and test methods for electric water heaters and ranges which have resulted in increased customer satisfaction and permit this relatively heavy demand equipment to be more economically served from distribution systems.

Miscellaneous smaller current consuming devices, radios, hand irons, fans, electric roasters, etc., have been improved and beautified. Their appeal and convenience has led to an ever increasing roster of appliances to be found in the average home. Some progress toward simplification and adequacy in inside wiring has been achieved; further progress may be expected. Commercial electric cooking has made good gains in hotels and restaurants as well as in cafeterias maintained by industrials for their employees.

Electrical thermal processes for smelting, heat-treating and drying have gained greater recognition through the development of more efficient equipment coupled with increasingly accurate control. Welding, both arc and spot, has revolutionized many fabricating processes, eliminating the use of castings in many cases, substituting electric "tacking" or seam welding for riveting in others. Progress has been made in providing solutions for

serving the fluctuating high demand, low energy resistance type welder loads. New applications are constantly being made. Boiler drums and piping for high pressures are assembled by welding and the X-ray is used to check the integrity of the welds. The continued development of steel bodies for motor cars has led to demands for wider sheets and new completely electrified mills have been necessitated thereby. Their high demands coupled with wide fluctuations in their production activities are not altogether an unmixed blessing.

Air conditioning, long since used to a limited extent in process work, has been greatly accelerated, temperature and humidity control having been found to pay dividends in improved finished products and decreased spoilage. Its use for improving human comfort is growing tremendously in theatres, hotels, restaurants and department stores, and is making fair headway in our homes. A start has been made in the electric heating of office buildings and homes by the reversed refrigeration process and he would be rash who would deny that this type of heating, combined with summer cooling, may not in certain parts of our country prove a gratifying source of future revenue.

The foregoing brief catalog of the many varieties of energy consuming devices now connected to utility systems reflects the very diversified character of loading prevalent among all classes of consumers. The problems of delivering suitable electric services to these classes are becoming more and more analogous, though often differing greatly in the magnitude of the various factors involved. No longer, for example, can we dismiss the residential inductive load as inconsequential. John Doe may have a home-made welder in his basement shop. Refrigerator or heating system motors may cause objectionable flicker in neighboring homes if the secondary supply system is not carefully designed. The fluctuating loads of large industrials even though supplied at subtransmission voltage will generally be manifest in voltage variations on the substation bus and may in turn affect the quality of service delivered by the distribution system connected thereto. Briefly, our supply systems must be designed so as to properly serve any type of load without adverse effect on the supply of other types, which are now or may later be connected to them.

The accurate metering of rapidly fluctuating and of low power factor loads is being increasingly discussed. Several EEI Committees are manifesting an awakened interest in the subject. The Meters and Services Committee is giving it careful study.

The Future

In attempting to forecast the future of our industry it is well to consider past trends. We note a progressive decrease in average coal consumption per kwhr, but—while a reduction of 47 per cent from 3.2 lbs to 1.69 lbs per kwhr took place from 1919 to 1929, the reduction for the next 10-year period is but 19 per cent, or from 1.69 to 1.37 lbs per kwhr. So we find the fuel economy curve tending to flatten out rapidly and future gains, except in individual plants, will be correspondingly smaller and more difficult of attainment. It is doubtful if the gas turbine will become a factor in generation for some time, and the Diesel engine is still limited to relatively small units.

In this past 20-year period, generating capacity increased 3½ times to almost 37½ million kw and generated energy increased from 24½ to 123 billion kwhr, but the use factor is still below 40 per cent. The present capacity can comfortably furnish many more kwhr than it is now called upon to do, without danger of shortage, if the valleys in our load curves can be filled. Unfortunately the ideal 100 per cent system load factor is beyond attainment. If at the end of '39 we had been able to install a 1500-watt water heater in the home of every residential and farm customer, for off-peak operation, the resultant added load would have been almost equal to the total installed generator capacity and the night valleys transformed into the heaviest peaks of the 24 hours. The moral is that as off-peak load saturation increases, some of this load will have to be spread over other periods of the day and certain rate and service problems may result therefrom.

What is our rural and domestic saturation? Fig. 1, on which are plotted curves of population, number of homes and domestic consumers (including farms), indicates practical total saturation in 25 years, if present trends are maintained. The actual saturation in terms of consumers within reach of existing lines is undoubtedly considerably nearer 100 per cent than the 75 to 80 per cent of total saturation variously reported at the beginning of the year. Fig. 2 shows in ratio form the changes in consumers connected, energy sales, revenue and average rates for farms, residences, small commercial light and power consumers and for all other consumers lumped together. The great increase in rural distribution mileage has resulted in our having 2¾ times as many farm customers at the end of the decade as we had at its beginning. Since energy sales increased but roughly one-half as much and revenue only 20 per cent,

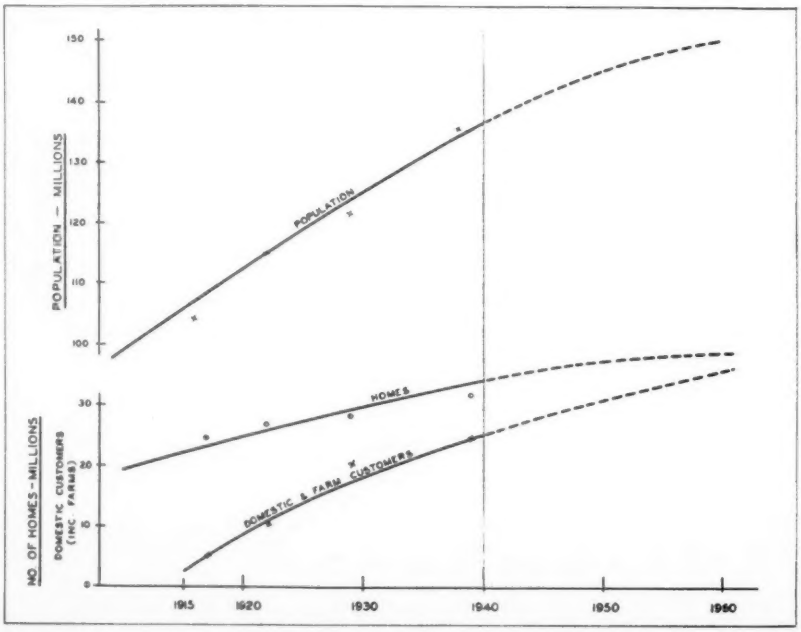


Fig. 1

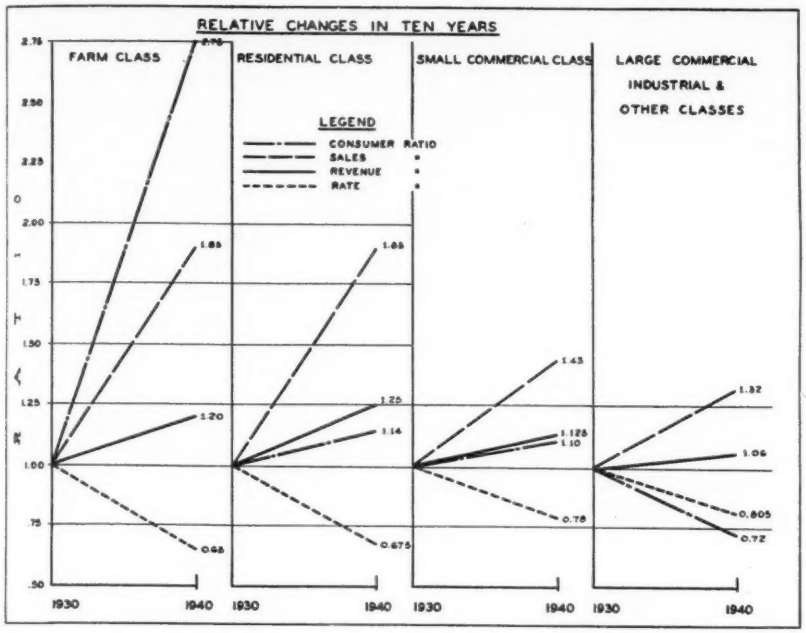


Fig. 2

two conclusions are obvious; one, smaller and smaller farms were added and, two, rate reductions intensified the decrease in average revenue experienced. To correct this, load building efforts must be directed to the introduction of relatively high wattage devices of inherently good load factor. In the residential field the consumer increase was but 14 per cent; usage increased 85 per cent and revenue 25 per cent. Here again the effect of lower schedules manifests itself. In the smaller commercial group an increase of 10 per cent in number was accompanied by an increase of 43 per cent in sales with but 12½ per cent increase in revenue. A parallel with the residential class is evident. Relative consumer increases were reasonably close in the two groups, relative sales and revenue double in the residential group. Efforts should be made to bring them at least to comparable parity. In the last group comprising all other classes, a decrease of 28 per cent in consumers is noted, but this decreased number used 32 per cent more energy and contributed 6 per cent more revenue than those on the lines in '30. This indicates that energy consumption per customer had increased 82 per cent and the average bill 46 per cent at the end of '39. Restoring the number of consumers to the 1930 level or better, and developing their use of current and consequently the revenue produced by it to that of the existing customers is no mean challenge to our sales organizations.

How can the engineer further contribute to giving our customers more and more for less and less? Fig. 3 indicates the fluctuations in total system investment per kw of installed generator capacity for over 20 years. A mean of $350 seems fairly well established and will probably not be decreased in the next decade. To keep it at this level may be a job well done. The 1940 budgeted system expenditures of 605 million dollars with an increase in generator capacity of not quite 1,300,000 kw reflect a total rate of $465 per kw of generating capacity to be installed this year, which will bring up the average total system investment to $345 at its close. The average investment allocated to transmission and distribution for the years 1938, 1939 and 1940 is 60 per cent of the total and it is largely in this field that the engineer must attempt to reduce expenditures. Production, transmission and distribution efficiencies will increase but the trends indicate a substantial reduction in their rates of increase with incremental gains more and more difficult of achievement. Improved load factors will help efficiencies. On the other hand, industry will doubtless be confronted with increased costs for fuels and other materials and with increased labor costs. Both will adversely affect our construction costs and operating expenses. And let us not forget taxes, for surely our governments will not.

The Challenge

It is to be noted that in general no revolutionary developments were achieved in the past decade. Progress was largely confined to increased ratings, incremental betterments of efficiencies, refinements in design and greater dependability. Nor does it seem to the author that any fundamentally new concepts for more efficient production, transmission or distribution of electrical energy are liable to be evolved and trans-

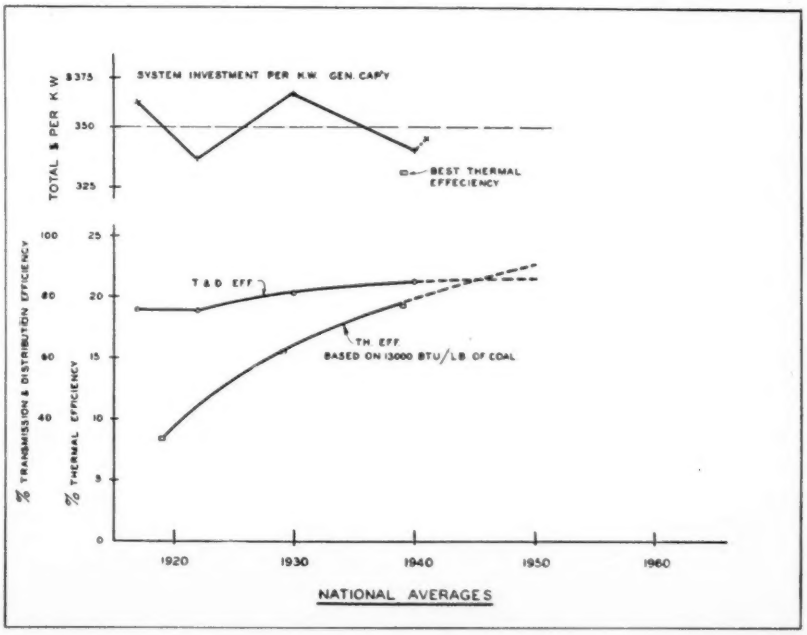


Fig. 3

lated into practice in the years immediately following. If true, no large single economies can, at this time, be predicted and the need for careful search of methods of reducing costs, here a little and there a little, so that substantial aggregate results may be obtained, is emphasized.

The coming years, therefore, present a vigorous challenge. Load building must go on apace with emphasis on fuller use of existing facilities. Investment must be kept at a minimum without sacrifice of safety or reliability. Construction methods must be studied to further reduce unit costs. Maintenance schedules must be analyzed and the intervals between routine maintenance periods lengthened to those maxima which our growing experience indicates as sufficient to keep the various classes of equipment in good operating condition. Operating methods must be studied, and modified if need be, to yield the highest obtainable overall efficiencies, but not at the sacrifice of service reliability. Inventories should be critically examined and kept at the lowest figure which necessity and obtainable deliveries on replacements indicate as reasonable. In order to accomplish these aims the helpful free exchange of ideas and methods which has been characteristic of engineers in their dealings with one another must continue, and no better forums for such exchange will be found than in the technical committees of this association.

Detailed Engineering Developments

Outlined below are a few of the items of major progress achieved during the past decade in the development and manufacture of equipment and materials for the production and utilization of electrical energy. Credit is due to the manufacturing organizations for many more items than can possibly be recorded herein.

Rotating Machinery

In general, the advances made in the design and manufacture of major rotating machinery have been along the lines of improved fabrication methods, more efficient use of materials, and improvements in insulation, rather than in more spectacular achievements.

In d-c machinery the introduction of the commutating pole some 20 years ago seems to have marked the last major improvement. Rotary converters and motor-generator sets and motors have increased in size and number due chiefly to increased developments in the chemical and steel industries. The large capacity (up to 5500 kw) mercury arc rectifier has invaded the field of the rotary converter in chemical reduction work and may eventually supplant it. Units used for the supply of d-c networks have been increasingly equipped with load-limiting devices to facilitate picking up a dead network in the rather remote eventuality of a complete shutdown.

In the turbine-generator field, there has been a steady development in size of 3600 rpm units and in improved operation of the combined steam-electric units. Direct-connected exciters have given some difficulty, but in newer units satisfactory exciter performance is being reported. However, it may be necessary to accumulate experience over another ten or more years before all design problems inherent to large high speed units may be said to have been completely solved. Hydrogen cooling has been applied to these high speed units in many cases and to some very large 1800 rpm units. The first hydrogen cooled generator was placed in operation in Dayton in 1937.

Hydrogen cooling had previously been used in connection with large synchronous condensers and frequency-converters. There is a marked tendency to install such units in the open over a pit to give accessibility to the parts. Hydrogen cooling systems are giving satisfaction and leakage is negligible.

There has been an increasing tendency to go to double winding for generators of large capacities and also to units generating voltages of the order of 16 and 23 kv.

Motors have been steadily improved and developed to better fit the needs of special applications. There has been a trend to enclosed machines to exclude dirt and foreign substances, but in one case the reverse trend has been utilized for producing a motor for textile drive that will permit the lint to pass through it without collecting any in the air passages. Cooling of motors by air or carbon dioxide under pressure has been resorted to for large motors in hazardous-gas locations. Such machines need not be as rugged as explosion-proof designs nor as tightly sealed as hydrogen-cooled equipment. Steel mill requirements (1937) have called for motors of 5000 hp and motor-generator sets of 7000 kw capacity. Numerous improvements have been made in fractional horse-power motors, making them increasingly adaptable for use with refrigerators, oil and gas furnaces, domestic stokers, etc.

Circuit Breakers and Fuses

In the year 1929, the Deion oilless breaker for voltages of 15 and 25 kv with interrupting capacities up to 25,000 amperes was introduced. Interrupting time including relay time was of the order of 3 cycles. These breakers were found particularly adaptable for use with power supply to mercury arc rectifiers used for d-c electrified railway operation. Oil breakers rated 3 million kva at 250 kv were manufactured. Herkolite explosion chambers for application to high voltage oil breakers appeared. In 1930 the Deion grid was applied to oil breakers. In 1934 "Ruptors" were available. All of these devices served to materially increase the rupturing capacity and reduce the interrupting time of oil breakers. Many existing breakers were modernized by their installation. Silver contacts began to be largely applied to heavy current carrying parts in 1931. A year later breakers using non-flammable liquids were developed.

The 287.5 kv impulse type Boulder Dam Breakers were developed in '33 and the commercial product installed three years later. In 1936 breakers of similar rating and speed (3 cycles) of the conventional oil type equipped with Deion grids were also furnished for this project. In 1935 a 161 kv, 1.5 million kva compressed air type breaker for outdoor use was announced. The cross oil blast principle was extended to practically all the large breakers of one manufacturer and parts designed so as to permit the modernization of existing units in service. Meanwhile, breaker operating speeds have been increased so that standard breakers are guaranteed to operate in 8 cycles from the time the trip coil is energized, and usually to operate in from 5 to 6 cycles. Three-cycle breakers are available for special applications.

All through the decade, improvements and developments have been made in metal-clad gear. A preference for air insulation rather than oil or compound filled gear seems to have developed. In 1939 a number of new types of oilless breakers were put on the market. These took the form of water breakers, magnetic breakers, and air blast breakers. Further developments are in the offing.

High-speed, heavy-duty reclosing breakers for transmission lines have been developed with total operating times from instant of energizing the trip coil to reclosing of the circuit of the order

of 18 to 20 cycles. Small reclosing breakers for pole mounting on distribution lines, especially in rural territory, are available and give satisfactory operation.

A number of manufacturers furnish three-shot reclosing fuse equipment in voltages as high as 46 kv, and these are being increasingly used to improve service. Fuse characteristics and ratings have been greatly improved and reasonable selectivity is available so that fuses nearest the source of supply will ride through the faults which blow those nearest the location of the trouble. Single shot branch fuses which coordinate with fast reclosing station breakers are also available.

Transformers and Regulators

In 1929 and 1930 transformer constructions effectively preventing the piling up of lightning surge voltages on the end turns of the windings made their appearance, since which there has been no outstanding improvement in design. Such construction is now available in transformers as small as 200 kva at 44 kv and higher voltage ratings. In general, larger units have been designed, complexities are developed by the demand for three- and four-winding units for special cases; load ratio control has been increasingly required. Phase control in conjunction with voltage control has been built into units designed for tying two ends of a transmission loop together. The use of supplementary fans or of auxiliary water cooling automatically or manually controlled to provide overload capacities of 33 per cent for normally self-cooled transformers has increased considerably. Other improvements have been in details of construction and insulation, in bushings and in the production of equipment capable of withstanding lightning surges of a high order of magnitude, which capability is proved by surge tests. While the conservator type of transformer is still very much used, the use of gas-sealed units is increasing. Self-cooled fan equipped units of a maximum rating of 66,667 kva, 3 phase have been produced (1939). Improvements in design have also resulted in reductions in over-all sizes and weights and in some cases exciting currents have also been reduced.

Transformers filled with non-flammable liquids introduced in 1934 are being made increasingly available and some self-cooled air transformers have also been installed, in locations where the danger of possible oil fires warrants their additional cost.

Competition is being offered the induction regulator by the step-type regulator, and while both may be obtained for the lower distribution voltages, for voltages above 5000 volts the step-type is more generally employed.

Regulator developments have been marked by refinements and improved electrical and mechanical construction. The necessary auxiliary devices are attached to the regulator case, avoiding the necessity of supplying switchboard panel space for their installation. For outdoor installations, suitable weatherproof housings are supplied to encase the auxiliaries. In addition to developing the station type for indoor and outdoor use, branch feeder regulators and branch boosters have been developed for use on long branch circuits extending beyond the effective range of the station regulators.

The use of non-flammable cooling liquids has also been extended to regulators.

Electronic Devices

Progress has been marked in this field. Power tubes of various types appeared in the early thirties, the most important of which are the grid-controlled and Ignitron types, the Phanatron and the Thyratron. There has been a transition from glass to steel, and steel tank mercury-arc rectifiers of unit ratings of 5500 kw have been successfully applied (1938). For the larger sizes continuously exhausted tubes are preferable to the sealed-in types, and water cooling is necessary.

A trial 150 kw substation installation of the Phanatron type was made in Boston (1932) in connection with d-c network supply. The Thyratron variable speed a-c motor was installed at Logan with good operating results in 1936. Tubes have been applied experimentally (1934) to furnish machine excitation, but as the excitation voltage may drop simultaneously with the station bus upon the development of a fault, they seem to be unsuitable for use as generator exciters in stations as now designed. Electronic voltage regulators in connection with motor-exciters have been successfully employed, however. Industrial and commercial applications have grown rapidly, a list of which is far too great for mention here. Recently (1939) mobile substations employing Ignitron arc rectifiers have been constructed for use in coal mines. In general, electronic equipment, where applicable, has been found to do a given job better or to do that which previously was impossible of achievement. Their greatest value to the utility industry lies in carrier-current relaying and metering and in voice communication either by carrier or space transmission, the latter chiefly to mobile units from a central dispatching point.

Mention should be made of an experimental constant-current d-c transmission system. The development of this method of transmission for high-voltage large capacity circuits is still in the future.

Lightning Protection

Extensive field observations and intensive study of natural lightning phenomena and characteristics have continued throughout the decade. As a result of these and other joint industry activities, transmission line protection has been improved to a point where interruptions are much reduced and terminal equipment subjected to far less severe duty from incoming surges. The adoption of the proposed basic insulation level "withstand" voltage standards for various types of equipment developed by the Joint Committee on Insulation Coordination should result in further improvement in performance. Very fast relaying is also relied upon to minimize damage when a lightning flashover takes place.

Capacitors

The use of capacitors has been greatly extended. They are primarily applied for power-factor correction on primary distribution circuits (for which use they have been systematized for pole and outdoor mounting) and in factories. In general, they are filled with non-flammable liquids. Specifically they have been applied to spot welders, to small motors to improve their starting and running characteristics, and to numerous control devices for special purposes. Their application in high-voltage bushings to obtain relay operating potentials continues.

Cables and Wires

The decade has seen the solid type of paper-insulated, lead-covered cable for high voltage service gradually being supplemented by the oil-filled type. In general, this type of construction has been too expensive for cables below 60 kv. For voltages of 15 to 40 kv the new gas-filled cable offers possibilities apparently equal to the oil-filled at more reasonable cost.

Synthetic insulations have been widely applied to many wires and cables for voltages 15 kv and less, and their use is extending. New heat resistant insulations have been developed permitting higher loadings and reducing the weight of copper necessary for a given circuit. The so-called thin wall wires for interior wiring have been developed permitting a greater amount of copper to be installed in a given size conduit, thus helping to relieve the "bottle-necks" so often hampering the installation of more adequate facilities in existing buildings. Improved enamels are being applied to wires used in the manufacture of coils for various types of equipment.

Meters and Instruments

Continuous progress has been recorded in the design of meters, instruments and relays. The socket-type watthour service meter was developed, through standardization the number of ratings of induction meters has been greatly reduced, with resultant decrease in prices (1937). Refinements and standardization of case sizes and mounting dimensions within manufacturing organizations has been accomplished with regard to most instruments and relays. Current transformers have been simplified and standardized. Relay developments have been continuous. Manufacturers will shortly furnish on all factory-built boards relay assemblies which will plug into sockets permanently mounted and wired on the boards. Relays may thus be removed and tested under more favorable conditions and at lower costs. Eventually this method of installation may be extended to all instruments, duplicate devices being installed while the originals are being held out for test.

Miscellaneous Materials

Extensive research has continued to produce a large number of new materials in the form of alloys, plastics, synthetic and fiber-glass insulations, each group of which fills some particular niche in the manufacture of electrical equipment in a better way than did its predecessors. An attempt to enumerate them, their properties and uses is far beyond the scope of a review such as this.

Lighting

Great strides have been made in raising illumination standards for both interiors and exteriors. The new fluorescent type of lighting with which power factor corrective devices are now incorporated is probably the most spectacular and the fastest growing. Improvements have been made in established types of lamps and new types introduced. There are special lamps for drying and baking purposes, operating at low filament temperatures, new lamps radiating ultra violet for germicidal uses, improved sun lamps, photographic lamps, etc.

Highway lighting has made large advances and the reduced number of traffic accidents resulting from increased road illumination will undoubtedly powerfully stimulate the more adequate lighting of all our principal highways. One installation is reported yielding an average illumination in excess of 5 foot-candles on the pavement. Sodium lighting is continuing to gain in popularity for heavily traveled highways. An increased number of stadiums has been equipped with powerful floodlighting to make possible the playing of ball games and other competititive sporting events at night.

Electro-thermal Applications

Aside from the use of electricity for lighting and as a motive force and for its control, probably the next most disseminated use of this form of energy is in its application to widely varied thermal processes.

Improved apparatus is available for cooking, water heating, steam generation, space heating, annealing and smelting. Furnaces with controlled atmosphere have been developed for use in alloy production and for the non-oxidizing heat treatment of metals. An immersion unit heated salt bath for heat treating aluminum is available, as well as electric furnaces for powdered metallurgical processes. The use of electric furnaces for the smelting of ferrous and non-ferrous metals has grown exceedingly. High frequency heating is also being extended for both heat-treating and smelting.

Welding has been improved and new processes and machines developed greatly increasing the scope of the work which may be done. Thyratron control was applied in 1932. Heavy parts may be welded together by the successive application of welding current by Thyratron-controlled impulses, which prevent the melting of the stock but yield welds of very high strength. The electric supply characteristics and efficiencies of spot and seam welders have been greatly improved; electronic control yields uniform results; arc welders continue to be one of our most useful electrical tools.

Other Fields

No attempt has been made to detail the notable progress achieved in electrical fields not intimately connected with the central station industry such as transportation by land, sea and air, nor in the fields of signal transmission, sound and image, by wire or through space. The continued development of electrical devices as tools for modern research and for industrial investigations, for medical use, both for diagnosis and for curative or prophylactive treatment, has perforce been ignored.

New Boiler Feedwater Report Ready

The Joint Research Committee on Boiler Feedwater Studies, through its secretary, Mr. J. B. Romer, of Babcock and Wilcox Company, announces the availability of the fourth progress report of a subcommittee charged with listing important patents issued which relate to the Committee's subject.

The report lists the pertinent patents cited by *Chemical Abstracts* from November, 1938, through November, 1939, and by the *Patent Office Gazette* from October, 1938, through October, 1939. It is offered for sale through the American Society of Mechanical Engineers Technical Committees Department at the Society's headquarters, 29 West 39th Street, New York, N. Y., at a cost of 25 cents a copy.

Only a limited supply of the first three progress reports is now available.

New Recording Paper

A novel electro-sensitive dry recording paper, Teledeltos, developed by The Western Union Telegraph Company, has now been made available to science and industry in general. A large electric power company, it is reported, has successfully used the paper in measuring the operating time of relays.

The product is an electrically conducting sheet covered with a material which presents a permanent change in color at any point where a current of electricity passes through it, but is impervious to exposure to light and is not affected by atmospheric conditions. No processing is necessary and the record is ready for immediate use.

Teledeltos is being marketed directly by Western Union.

Distribution Meets Its Responsibilities

By H. P. Seelye
Senior Engineer, The Detroit Edison Company

Address Before the Fourth Session of the Eighth Annual Convention of the Edison Electric Institute, Atlantic City, N. J., June 5, 1940

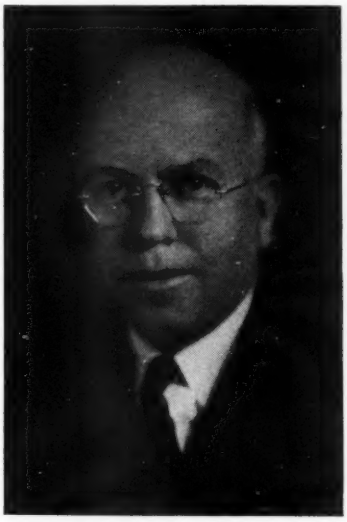
IN every industry, the problem of transporting the product from the point of manufacture to the ultimate consumer, effectively and efficiently, is one of paramount importance. No matter how well an article may be made, or how ample the quantity manufactured, if the customer is to be satisfied, it must reach him in good condition, in sufficient amount, and at the proper time and place to suit his convenience. No matter how low the cost of making the goods may be, the cost at the customer depends to a large extent on the cost of bringing them to him. In this regard the electric power industry is no exception. Whether the product is automobiles, breakfast cereals, or kilowatthours, a large part of the responsibility for the quality of the service given to customers and the cost of rendering that service lies in the distribution facilities.

It is the purpose of this paper to discuss the distribution of our product, electric power; to give a conception of the responsibilities of the distribution system as a part of the power system; to indicate some of the particular requirements of the distribution problem from the engineer's viewpoint; and to recount some of the accomplishments which have been made in distribution during the past decade or so, toward better service and lower cost. Although the distribution system rightly includes the major transmission system and substations, this paper will deal more specifically with what is sometimes called "local distribution," that is, the facilities between the substation and the customer. It is this part for which the engineering approach differs most, and also it is this part which is least evident and least understood by those not closely concerned with it.

What Are the Responsibilities of Distribution?

Good Service Depends Largely on Distribution

There are two criteria by which the quality of electric power service is judged. The first is its reliability, that



MR. SEELYE

is, its freedom from interruptions. The second is the voltage regulation at the customer's service, or how close the voltage is maintained to nominal service voltage. In considering these criteria, it is significant that every kilowatthour sold to customers by a power company must pass to those customers through the distribution system. This is indicated on Fig. 1. The excellence of service rendered to those customers depends very largely on the design and operation of that distribution system.

Between the power generator and the individual users lie many miles of wire. On the Detroit system, for example, the current travels about five miles to reach the average customer. The farthest one is nearly 100 miles away from the closest generator. Some of this wire is no more than ⅛ inch in diameter and none of it much bigger than your thumb. Part of it is strung in the air on poles, where it is subject to damage from lightning storms, wind storms, ice storms, and the small boy with his kite strings. The rest of it is buried in the ground where storms cannot get at it but workmen with pick and shovel can, and where it must be insulated with materials whose occasional breakdown is expected. An interruption in service at a generating source or on a major transmission line is, of course, serious from the company's point of view in that it interrupts a great many customers. For the individual, a break anywhere in the wires connecting him to the generator is just as much of an interruption, and to him just as serious.

While it is possible in areas of high load concentration to provide reserve facilities which can maintain service in case of a failure of a supply circuit, for most of our distribution, the scattered nature of the load and of the distribution lines, makes any such complete provision prohibitive. This is obviously true in the extreme case of farm lines serving widely separated rural customers.

The problem is to construct and operate these lines so that they will withstand all ordinarily anticipated troubles, so that they can be repaired quickly if a break does occur, or so that service can be thrown over temporarily to some other circuit, and to do this within a cost which is compatible with the revenue which can be obtained from the load being carried. This problem becomes more difficult as the uses for electric power increase, and application is extended to those services for which an interruption is more serious. In recent years the increase in such equipment as motors and ignition for heating plants, or, on the farm, such devices as milking machines and brooders, has made service reliability more important than when the customer had only lamps and small devices for intermittent use.

As an example of the contribution which various parts of a system make to service outage for the average customer, Fig. 2 shows data for the Detroit system. The vertical scale indicates the average frequency of outage from each source; the horizontal widths are proportional to the average duration. The relatively small part attributed to bulk power supply compared to that due to troubles on

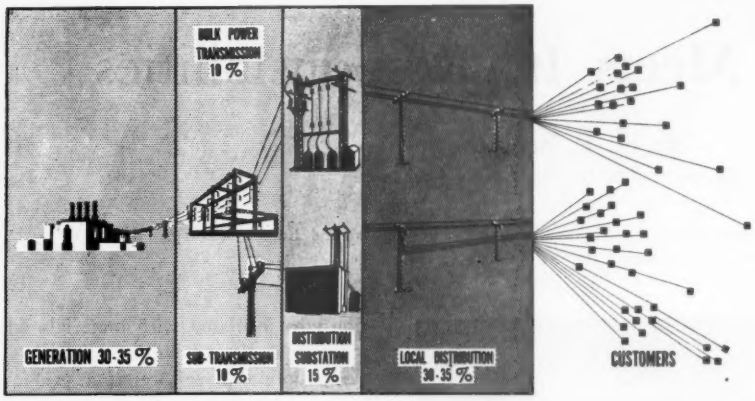


Fig. 1—Major Components of Electrical Plant and Relative Investment

primary distribution circuits is evident. Of course, much attention has been paid to reducing outages from power sources and providing reserves for them. The relative costliness of making equivalent provisions on the distribution lines is indicated by the fact that, even without such provisions, the investment per kw in local distribution is about equal to that in generation.

The second element of good service which was mentioned was good voltage regulation, or the maintenance of voltage at the customer's switch without wide variation throughout the day. This is mostly a responsibility of distribution. Whenever current is passed over a wire, the voltage drops and this drop is proportional to the amount of current. At light loads the drop is small and the voltage at the customer's end of a line will be very nearly that at the sending end. Under heavy load, the drop is larger, the amount depending on the amount of load and nature and design of the circuit. Even though the voltage be regulated perfectly at the generators and be held within small limits at the substation, if the distribution circuits are not properly designed, the customer's voltage will be poor. It may vary through an undesirably wide range at different loads and be subject to annoying dips due to suddenly applied loads such as motor starting currents. The distribution engineer overcomes these difficulties by properly proportioning wire sizes to load current and length of circuit, and by the use of regulating equipment, automatic voltage regulators, transformer taps, capacitors, etc. It is on these that the quality of service and customer satisfaction depend.

Distribution is in the Customer's Back Yard

The distribution system is the part of the company's property with which the customer is intimately acquainted. He rarely sees a power plant, even from a distance. He may pass a substation occasionally, but is likely not to recognize it as such. Distribution, however, comes into his street or his back yard with its poles and wires. Its service equipment is attached to his house. How often is the opportunity for creating good will or bad will by the appearance and condition of these structures recognized? Considerable care is usually taken with station buildings and other company property to make them presentable and in harmony with their surroundings. Isn't it probable that similar attention to the distribution structures would be fully as worth while?

Distribution Accounts Form an Important Part of the Cost of Electric Service

It is obvious, of course, that since distribution plays such a large part in the rendering of electric service, it will also represent an appreciable part of the cost of such sevice. The total investment in a representative large system is divided roughly as follows:

Generation and bulk power transmission	35 to 40 percent
Sub-transmission, substations, and distribution	50 to 55 percent
Miscellaneous	10 percent

If we consider the electrical plant only, it will be divided somewhat as follows:

Generation	30 to 35 percent
Bulk power transmission	10 percent
Sub-transmission	10 percent
Distribution substations	12 to 15 percent
Local distribution	30 to 35 percent

This is shown graphically in Fig. 1, the areas representing relative percentages.

It is apparent that the generating plants, which loom rather large in the minds of most of us, represent an investment no greater than that in the poles, wire, transformers and cables of the local distribution from the substation to the customer. If the distribution system is construed in the larger sense, which include transmission lines and substations, the investment is about twice as large as that for generation.

Considering operating costs as well as fixed charges on investment, the cost of electrical energy to the ordinary residential customer is made up of three nearly equal parts, the cost of generation and transmission, cost of distribution, and commercial cost (metering, billing, general expense, etc.). It should not be inferred from that that the distribution costs are out of proportion. In other industries similar conditions prevail. A recent book entitled "Does Distribution Cost Too Much" issued by The Twentieth Century Fund states that the average cost of distribution for all commodities in this country is estimated to be 59 percent of the retail price. This includes the elements of commercial cost and transmission as well as actual distribution cost. It should, therefore, be compared with a total of the order of 65 to 70 percent for distributing electrical energy. Naturally, the actual costs vary widely with different products. For example, breakfast cereals are listed at 50 percent, canned tomatoes at 34 percent, raw cabbage at 82 percent, etc. It should be expected that the distribution expense would be high for a commodity like electrical energy which renders a direct and continuous service to the home of each customer. It is evident that the proportion of distribution costs in the cost of electrical energy is not out of line with the proportion pertaining to other products.

The main purpose in giving these figures in regard to distribution costs is not to justify or criticize their magnitude, but rather to point out that for every dollar a power company invests in its electrical property, about 33 cents is spent at the discretion of those responsible for distribution. The importance to the company and its customers of the proper and careful use of that money is obvious.

Engineering on Distribution Is Different

Engineering on the distribution system differs considerably in several respects from engineering on other parts of the electrical plant. This is due to the difference in the type and location of the equipment. Distribution is a widely scattered aggregation of small units. Con-

trasted with the production man's four or five power plants, with half a dozen large generators in each, all under continuous and close inspection, a distribution system, like that of The Detroit Edison Company, for example, contains over one-half million poles, 75,000 individual distribution transformers, and over one-half million separate services, spread over 7,500 square miles of territory.

Individual engineering design for each line or each section of the distribution system is out of the question. The establishment of general standards for items of material and equipment and for their application to the job are not only important but essential. The field engineering then becomes an intelligent application of these standards to fit known local conditions. A mistake in deciding on a standard is multiplied many times over and it may be years before it becomes evident and can be corrected. For example, if the standards for pole strength are set too high, even by one pole Class, an excess investment of about ¼ million dollars results eventually on a system having one-half million poles. On the other hand, if the standards are set too low, storm damage may become excessive as time goes on and outweigh any initial saving in investment. Such mistakes are hard to recognize and to correct since they are applied in relatively small amounts, to a large number of scattered items under a great variety of physical conditions, and intermingled with older plant of various ages.

It is important that simplicity and ruggedness in this equipment be emphasized. The lines are on their own. They are battered by wind, snow, rain, and sleet. They are loaded with ice accumulation one month and scorched by the summer sun another. They are attacked by rust, decay, insects, birds, boys, and vehicles. They are shaken, vibrated, whipped, and generally mistreated. Only occasionally does some one come around to see if they are getting along all right unless a failure occurs. For such service the devices used must be good and they should be as simple as possible. Complicated gadgets must be avoided—and an innumerable lot of these are offered to solve all our problems. Otherwise, service quality will go down and maintenance costs will go up.

On distribution, the practice of ten-cent-store economy is particularly profitable. A few cents saved on a particular item may look small but the engineer must remember his multiplication table. The quantities of small items, bolts, insulators, pins, braces, etc., used each year are enormous, and a little saving in each should not be ignored. To give a small but typical example, we formerly cut the tops of our poles to a peaked roof but this was found to be unnecessary. It cost something like 15 cents, and what is that on a three hundred million dollar system? For 30,000 poles a year, however, it amounts to $4,500 each year, which is equal to the fixed charges on an investment of about $30,000. Such a saving on a single construction project would be considered well worth while. The results of such engineering can rarely be shown in large lump sums. The approach must, in most cases, be by the process of sampling, such as that just illustrated.

Distribution Has Made Progress

Distribution has made marked progress in meeting its responsibilities to better service and lower cost. Engineers, manufacturers, and the field construction men have all contributed their part. In the remainder of this paper the stories of some of the more important developments will be outlined briefly. While the past decade has witnessed a marked growth in the application of these improvements, a number of them were initiated in preceding years, and, for completeness, that background will be included.

Farm Lines

Prior to about 15 years ago, very few farmers had electric service. In some of the more thickly populated and prosperous sections, lines had been extended a short distance from towns but these were, in general, of the same type as those used for urban distribution. That is, weather-proof copper wire was used, the spans were about 150 feet, and not much attention was paid to pole economy. The cost of these lines was relatively high considering the scattered nature of the load and hence was one of the main factors retarding development.

The wire manufacturers finally made available conductors of considerably higher strength than the copper wire which had been commonly used. These were the steel-cored aluminum and copper covered steel, and, later on, combinations of the latter with copper. They allowed longer spans to be used than had been thought feasible. Experimentation was stimulated to determine how long-span lines with small conductors of this type would behave under service conditions. The results were favorable. Attention was given the poles to make them as small as allowable for the expected storm-loads. Also the various accessories, hardware, transformers, etc., were scrutinized to reduce their cost.

The result was the establishment of a type of construction for rural lines using high-strength, bare conductors, and minimum-sized poles in spans of 400 to 500 feet at a cost of something like one-half that of the older type of line. Two typical examples of farm lines, differing somewhat in details, are shown in Figs. 3a and 3b. That is, this construction allowed lines to be built, complete for service, at a cost varying from $700 to $1,000 per mile as compared with $1,500 to $2,000 for the former urban-type lines. This development has played a large part in the program of extending service to rural territory which, in some localities, has already reached nearly all of the possible customers. On The Detroit Edison Company's system, for ex-

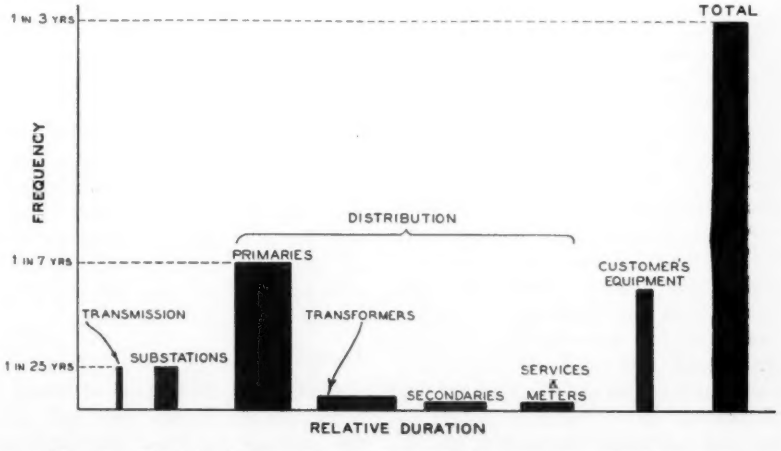


Fig. 2—Typical Average Service Interruption per Average Customer

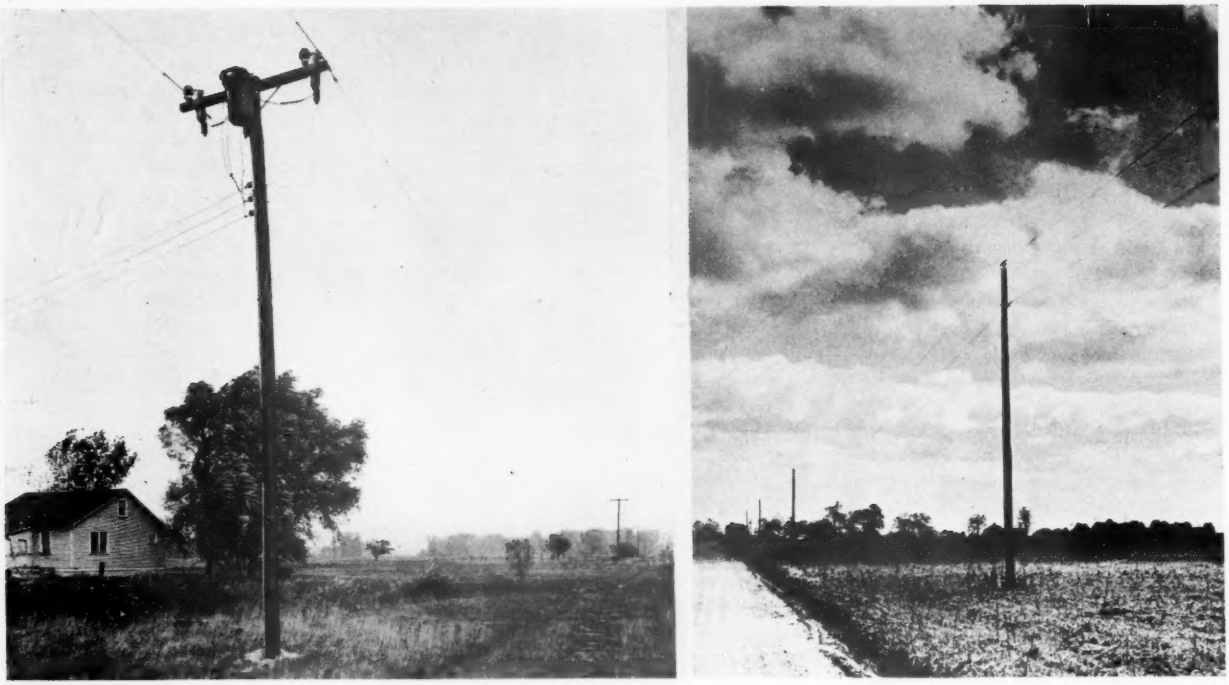


Fig. 3—Typical Farm Line Construction

(a) Crossarm type (b) Pin and Bracket Type

ample, 92 percent of the farms have service available.

It should be added that this farm line construction was developed in practically its present form more than 10 years ago and is not, as is sometimes inferred, a product of the activity of the past few years. The first farm line on The Detroit Edison Company's system was built in 1923 and the major program of rural electrification was undertaken in 1928. Similar developments took place elsewhere during this same period. The widespread building has developed mostly in the last decade, however, as is well known.

A-C Networks

The original systems of distribution were by direct current. Later on, alternating current distribution was introduced and its advantages in lower cost, and greater flexibility to meet growing loads was recognized. Direct current was retained, however, for the downtown section of the larger cities, due largely to the fact that the direct current network with storage battery reserve was more reliable than any alternating current system which had been devised. In 1922 the United Electric Light and Power Company installed in New York the first alternating current network system using full automatic equipment, the so-called a-c low voltage network. In essence this consisted of a grid network of a-c secondaries, somewhat similar to the d-c network, fed by transformers connected alternately to two or more primary feeders. Reverse power circuit breakers on the transformers enabled a faulty feeder to be disconnected and service to be continued automatically from the remaining feeders. The quality of service given by this network compared favorably with that of the d-c network and at the same time had the advantages in economy and flexibility pertaining to a-c supply. This scheme of distribution has been developed and perfected until today it is accepted as an adequate means of serving densely loaded areas where high reliability is essential and lines must be underground. One hundred and twenty cities have such networks in operation.

It is impossible to estimate closely what the economical advantage to the industry has been from the introduction of this new type of distribution. It can be said, however, that the total cost of the a-c network for heavy load concentrations is, on the average, not over 75 percent of that of a d-c network.

Lightning Protection

One of the chief causes of service interruption has always been and still is the damage to lines and equipment caused by lightning. For example, on the Detroit Edison system, 25 percent of the total long service interruptions are attributable to this cause. In addition to the loss of service, the cost of repairing and replacing damaged equipment is also a considerable item. During the past 20 years, however, the art of lightning protection has made remarkable progress and the damage today is very much less than it was formerly and is continually being reduced.

Up to about 1920 very little was known about the real nature of lightning. Certain protective means were employed — lightning arresters were available and ground wires were used on some transmission lines. The design and application of these were, however, based largely on unproved theories and limited experience rather than on accurate data. The introduction of adequate means for measuring lightning strokes and surges, the klydonograph, the cathode ray oscillograph, and surge recorders, together with apparatus for producing artificial lightning in the laboratory opened the way to definite knowledge about this phenomenon and the behavior of protective equipment when subjected to it. Some very surprising things have been discovered. Surges of millions of volts and currents of more than 100,000 amperes have been measured, with surge fronts rising from 0 to their peak in a millionth of a second or so. The fact

has been established that lightning does strike twice in the same place, in fact many strokes consist of a series of separate discharges and last sometimes for a second or more.

Today we have reached a point where very effective protection against lightning damage is possible. The degree of protection afforded by a given design can be predicted quite closely. That degree can be increased, by increased expenditures, to a level at which only rare cases of damage are to be expected. The economical level depends, of course, on the relative importance of the service.

On transmission lines the protection given by properly applied ground wires is now quite well understood. Their effectiveness depends on the number of such wires, their location relative to the wires protected, and the resistance of ground connections. The value and use of a counterpoise buried in the ground as a supplement to tower grounding has been well developed. In recent years the expulsion tube as been introduced. This is a cheaper form of lightning arrester, suitable for installation along the lines in order to discharge lightning surges from the conductors in case they are struck. One interesting new arrangement for wood pole lines, which is being tried, places one of the line wires at the top of the pole in a location suitable for a ground wire with this wire protected by expulsion tubes at frequent intervals. Fig. 4 shows such an installation on the lines of the Public Service Electric and Gas Company of New Jersey where the idea originated.

The impulse strength of insulators has been studied and the high impulse strength of wood in poles, crossarms, and braces has also been recognized. Wooden arms are sometimes used on steel towers for added insulation against lightning. Wooden crossarm braces are now commonly employed on wood pole construction for the same purpose, where formerly steel braces were customary. Guys are frequently insulated with wooden guy insulators.

On distribution transformers, the practice of protecting each transformer by lightning arresters has become general wherever lightning is troublesome. These small arresters have been perfected to a point where they can discharge high currents and still keep the voltage below the impulse strength of the transformers. The transformers themselves have been greatly improved in impulse strength, and considerable attention has been paid to the coordination of the impulse strength of the winding, the flashover voltage of the bushings, and the lightning protection used. A development of recent years has been the interconnection of the arrester ground connection with the grounded secondary neutral. This reduced the voltage between primary and secondary windings during lightning discharge. Along with this has gone an emphasis on low ground resistance for the arrester ground. The introduction of these measures has been quite generally reported to have effected a reduction of some 40 percent in transformer burnouts due to lightning. It also reduced the blowing of primary fuses, the reduction being as much as 75 percent on one system. Modern lightning protection has reduced transformer damage to relatively insignificant amounts. The percentage is of the order of ½ of one percent, per year, varying of course considerably between different localities.

Transformer Loading

Considerable attention has been given in many companies to the economical loading of distribution transformers. At one time common practice followed one of two extremes. On the one hand, the load on a transformer was allowed to grow until the transformer burned up or the voltage got so bad that customers complained; elsewhere the load was measured, but it was not allowed to get beyond the nameplate rating of the transformers. The former practice was not economical with a rapidly growing load and did not give the best of service; the latter also was not economical in the use of transformer capacity. It is quite customary now to watch the load on the transformers by periodic load measurements or load records. It has also been found feasible to take advantage of favorable field conditions such as low ambient temperatures and non-continuous loading, to carry peak loads considerably higher than nameplate rating. A recent survey of nine companies by the EEI Transmission and Distribution Committee showed the average criterion for replacement was when the peak load reached 145 percent of the transformer rating. The possible economy of utilizing distribution transformer capacity as fully as practicable, without going to a point where service is endangered, is considerable.

An average loading of 50 percent for a system is not uncommon. It is hard to raise this a great deal for scattered suburban and rural load, but urban loading can average well above 75 percent, and 100 percent or over is possible under favorable conditions. Distribution transformers constitute something like 3 percent of the total plant investment. An increase of one percent in the average loading from an average of 75 percent is equivalent to a saving of .045 percent of the total investment. For a 100 million dollar plant this would amount to a saving of $45,000 for each one percent that the average loading could be increased, or $450,000 if a 10 percent increase were possible.

Fig. 4—Protected High-phase Wood Pole Transmission Line

Secondary Design

In building the ordinary secondary distribution lines along streets or alleys, there is a choice of a large number of possible combinations of wire size, transformer size, and transformer spacing. A considerable amount of money can be wasted, however, by using a combination which is too far from the most economical. Large transformers cost less per kva than small ones but, for a given density of load along a street, they must be spaced farther apart. This in turn requires larger and more costly secondary wire to give proper voltage at the customers. On the other hand, too small

transformers and too small wire can be uneconomical as well as inviting troubles from voltage flicker, due to starting currents of small motors.

This problem has been carefully studied on several systems, the results being presented in papers before the Transmission and Distribution Committee of the Institute in March, 1934, and the AIEE in January, 1937. In general, it was indicated that wire sizes from No. 4 to No. 2 wire were most economical for the usual range of load densities. Fig. 5 is an example from one of the studies. Transformer spacings of the order of 700 to 800 feet are suitable. The difference in cost over a reasonable range of values, such as from No. 4 to No. 1 wire, is not great. When contrasted to a design using a considerably larger wire size, however, the difference may be of the order of $100 per 1,000 feet of line or about $6,000 per square mile of territory. This can amount to a considerable sum if the area served has many square miles.

In connection with secondary design, the increasing use of secondary banks should be mentioned. By tying together the secondary mains fed by a number of adjacent transformers into a continuous main or bank, voltage dips due to motor starting currents are reduced, the load is distributed better among the transformers, more uniform voltage is maintained, and service outage due to faulty transformers is decreased. This scheme is not new, having been used in a few places for many years. The greater use of motor appliances and the more careful attention being paid to quality of service have stimulated the wider adoption of the plan in recent years. This is one means whereby careful engineering has produced improvement in quality at little or no increase in cost.

Inductive Coordination

A problem in distribution quite different from those wich have been mentioned is that of coordinating the design of power circuits with those of adjacent communication circuits. When a power circuit is run parallel to and nearby a telephone or telegraph circuit, there tends to be induced in the latter voltages and currents which interfere with its proper operation. The difficulties encountered were originally very troublesome, particularly since the technical aspects were not well understood and the

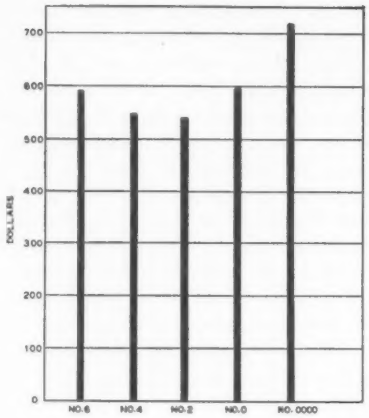


Fig. 5—Typical Cost of Secondary Line per 1000 ft

rights of both parties not well defined. These increased as lines became more numerous and power voltages were raised.

In 1923 a joint activity, called the Joint Development and Research Committee, was set up by the Bell Telephone System and the National Electric Light Association to study the problem and has been continued up to the present under the Edison Electric Institute. The results have been entirely satisfactory and of great benefit to both groups. It has been a very fine example of the possibility and value of cooperative effort by two industries with divergent interests. By both study and field tests the technical data necessary for a clear understanding of the major elements of power circuit influences, coupling between circuits, and communication circuit susceptibility, under the wide variety of conditions existing, have been collected and published. Means for prevention and coordination, applicable to both systems, have been studied and evaluated. General principles of cooperative action were agreed upon and have been followed in actual cases.

Today, while the problems still exist, they are settled, as a matter of course, by mutual engineering study. In most cases they have become merely routine application of accepted methods. Certain work still remains to be done and new problems will arise as conditions change in both industries. One notable step in the past few years is the establishment of acceptable conditions for the joint use of poles by the two parties with power voltages considerably higher than were formerly permissible.

Service Improvement

Several means have been developed in recent years whereby the quality of service to the customer may be improved.

Induction regulators for raising or lowering the voltage as the circuit load varies have been used for many years. These were usually applied only at the station ends of circuits and their cost prohibited their use in many places, even for this purpose. A line of step-type regulators and automatic boosters has been recently brought out at appreciably lower costs. These are applicable on the lighter cicuits and also at intermediate points along the line on long circuits. They make it feasible to hold service voltage within closer limits on scattered suburban and rural lines.

Another development of the past few years has been the small static capacitor for installation on distribution lines. They are made in relatively small units at considerably less cost than former types of capacitors. They may be scattered over a circuit or may be assembled in larger units at strategic points, or at the substation. They accomplish a rise in voltage together with a reduction in load current for loads of low power factor, thereby increasing the load capacity of the circuit if this is resticted by the allowable current. Properly applied, they can, under certain conditions, be a very useful means of improving service voltage and economy.

The sectionalizing of long or branching circuits in order that a fault on one section may be automatically cleared without interrupting service on the whole circuit has become prevalent. This practice has been promoted by the improvement in quality of fuses, making them more reliable and more easily coordinated from section to section. The introduction of reclosing fuses which automatically insert a new fuse after the first one has blown, and of the small reclosing circuit breaker for pole mounting has contributed to the reduction of long outages. These act to restore service after it has been interrupted by a temporary fault.

Several companies have set up rather comprehensive methods for analyzing their service outages in terms of average number and duration per customer and according to the part of the system on which it originates and the cause of the trouble. An example of such an analysis is shown in Fig. 2. A study of this kind can be used to good advantage in judging the relative value of spending money to

reduce outage on any particular location or type of equipment. It will sometimes be evident, for example, that trouble on a certain transmission line, which is annoying and seems serious when it occurs, is still not a large contribution to the service outage record. These records for six different companies were compared over a period of three years and the result reported before the Transmission and Distribution Committee in 1937.

Improvement in Materials

Improvement in the materials for line construction has been made in nearly every class or item. The results are better service or less cost or both. Any complete enumeration of these changes is obviously impossible but a few interesting ones will be mentioned.

Poles

Twenty years ago the majority of wood poles used were untreated. Satisfactory treating methods have been developed and the use of treated poles today has become quite general. An idea of the economy can be gained from the fact that the untreated cedar or chestnut pole had a life of something like 15 years, this varying considerably, of course, with locality and with individual poles. Proper treatment is expected to add not less than 10 years to the life at a cost of about $1.00 to $2.00 per pole, depending on the size. Since a pole in the line may represent an investment of the order of $15.00 to $20.00, adding 66 percent to its life leads to savings in annual charges of the order of 50 cents per pole per year. While 50 cents is not much for a single pole, for one-half million poles on a system it could mean $250,000 each year, a good return on the additional investment for treatment.

Wire

A laboratory investigation by the Utilities Research Corporation in 1930 led to the development of an improved covering for weatherproof wire, using air-blown asphalt of a specified quality for impregnation, and a better exterior finish. It is expected that this will add materially to the life of the weatherproof covering which constitutes something like 1/3 of the total weight of the covered wire generally used in urban distribution.

A recent development is a wire covering which has considerable insulating value, much more than that of the common weatherproof covering, but without an increase in diameter or weight. It is anticipated that such wire will be of considerable value in reducing outages due to wires burned down by accidental contact or foreign objects thrown over them.

Wire Connectors

Line splices and tap connectors for making wire joints without solder and without special tools have come into common use. It has been possible to eliminate soldering equipment from the construction wagons and work has been facilitated, particularly that of repairs and changes.

Cables

Considerable improvement in underground cables has been made. High voltage cable operating at 132 kv was first installed in Chicago and in New York in 1927 and has operated satisfactorily. Reduction in thickness of insulation on nearly all classes of cables has been found feasible and the standards have been modified. A large amount of study has been devoted to the improvement of lead sheaths and much has been accomplished. Non-metallic sheathed cables have been continuously improved and are finding increasing use.

A marked advancement in the technique of rubber insulation manufacture has been made in recent years. Compounds have been produced with special qualities of long life, high allowable temperature, moisture resistance, ozone resistance, etc. Rubber-like synthetics have found considerable use and the uses are rapidly increasing.

Insulators

One of the most notable developments in line insulators in recent years is the production of "non-static" or "radio-free" pin type insulators. Interference noise is produced on the high voltage lines by small electrical discharges in interstices under high electrical stress, such as under tie wires or between pin and insulator threads. The remedy has been to distribute the stress by application of conducting surfaces in or under the glaze on the head and the pin hole of the insulator, or by metal caps and threads. Several effective designs are now available.

Standardization

It has been mentioned that standardization is especially important in connection with distribution materials and practices. If properly handled, standardization can be productive of large savings and also be an aid to progress rather than an impediment, as is sometimes inferred. Standardization is really an application of good housekeeping and efficiency. For the individual company, it means the selection of those materials which are best suited to the work to be done, not too cheap to be good and not too good to be economical, and with as few varieties and as few sizes as are consistent with good workmanship. It means studying the application of these materials to the construction work, so that the best arrangements and the best methods can be chosen and made uniform throughout the property. "Best" includes considerations of adequate strength, safety, appearance, and economy. It further means continual scrutiny of the standards set up for the purpose of making further improvement or revisions as new ideas and new equipment become available.

For the industry as a whole, standardization means the agreement of users and manufacturers on certain qualities, sizes, shapes, dimensions, etc., in connection with materials so that they may be produced and used more economically. It reduces the cost of manufacture by allowing mass production and it reduces the cost of utilization by simplification of designs and varieties, by providing interchangeability, and by establishing definite quality ratings. Eventual economy is the chief object of standardization and should be the measure of its worth in any case.

In most of our companies, standardization of materials and methods has been given considerable attention. In some it has been carried to the extent of complete standardization control of materials, with written purchase specifications and careful inspection on receipt. This is accompanied by complete specifications for line construction standards, and standardized methods for construction forces, backed by routine school instruction for the workmen.

In the national field, the Edison Electric Institute has taken part in numerous standardization projects in cooperation with the American Standards Association, the American Society for Testing Materials, the National Electrical Manufacturers Association, American Wood Preservers Association, and others. To mention a few examples:

The establishment of a uniform system of classification for wood poles of varied species cleared up the former confusion in classifications and simplified the purchasing and using of poles.

The publication of specifications for various items of line materials, poles, crossarms, bolts, insulators, fuse cutouts, cables, etc., has

promoted simplification and uniformity in these items.

A joint committee of the EEI and NEMA has been working for the past two years to formulate standards for distribution transformers. Varieties of design to meet customers' requests had reached a number all out of proportion to the real necessities. In one case, 26 variations were reported in 3-kva single-phase transformers of one voltage class, many of them in details such as methods of hanging and bushing arrangements. This committee has just published its first formal report, setting up standards for transformers of 25 kva and smaller and 15 kv and less. The work is being continued on standards for the larger sizes. It is expected that uniformity in details will effect considerable economy in manufacture, and that this will be reflected in prices to the users. The simplified mounting which is part of the standard offers possibilities of additional savings in cost of line construction. The total production of distribution transformers in these sizes per year is worth something like $12,000,000 so that even a small percentage reduction in cost will mean a considerable amount. It has been estimated that the total savings to the industry resulting from this standardization will probably be well over $1,000,000 a year, in reduced prices and lowered construction cost.

Other Activities

The preceding paragraphs give an idea of the variety in the distribution problem and some of the things that have been and are being done to meet it. What has been said is by no means a catalog of all the activities, but should rather be considered as typical of the work which goes to make up distribution engineering.

A Look at the Future

Prophesy is always a dangerous and rather unproductive venture but it may not be amiss to point out a few of the probable future trends in distribution. The increasing use of electric power and its application to an increasing number of uses has led to the need for better quality in the service, that is better voltage regulation and less outage. Although present-day service quality is, in general, good, there is no reason to believe that the future will not bring still closer restrictions. As the use of power enters more closely into the necessities of our life, frequent or long interruptions or inferior voltage become less tolerable. Also, there is always a tendency to take good service for granted, once it is accomplished, and demand something better. It seems reasonable, therefore, to expect increased density of loading and, along with it, an increasing demand for greater perfection of service quality.

It is probable that the use of underground facilities will increase. This will be caused not only by the desire for improving the appearance of streets and other property, which is likely to be a factor, but also due to the increasing congestion of lines which accompanies larger loading. It is improbable, however, that the cost of underground distribution will ever approach very close to the low cost of overhead distribution which has been a major element in the rapid expansion of the use of electric power in the past.

It is sometimes stated that large opportunities for the reduction in cost of electric service lie in the field of distribution. If this refers to those systems—and there are some—on which distribution has been neglected—on which full advantage has not been taken of the improvements offered by modern engineering, the statement is true. If, however, it infers that in distribution there are large untouched opportunities for economy which have been heretofore overlooked, it is believed that this idea is a fond wish which will most likely lead to disappointment. The evidence that engineering in distribution has kept pace with engineering in other fields has been presented in this paper. Further progress is to be expected as it is in those other fields. No radical changes in materials or methods can be foreseen, however, which will lead to major reductions in the cost of distribution.

On the other hand, there are influences which portend a decided trend toward higher distribution cost. It was pointed out in the preceding paragraphs that the future prospect is for still more stringent service requirements and this, in general, implies greater expense. In addition there is the probable tendency toward higher priced construction, such as a greater use of underground lines. It will be difficult to counteract these influences toward higher costs. The outlook is, therefore, toward increased costs for distribution instead of reduced costs except for one factor. Quite a large part of the investment in distribution is in such things as poles and wires which can carry considerably more load without proportional increase in cost. In addition to this, most of the cost of distribution lies in the "ready to serve" investment, or the charges on the investment necessary to meet the peak demand in kw, rather than the consumption in kwhrs. A considerable increase in kilowatt hours is possible by enlarged use of energy by the customer, without increasing the demand appreciably and hence without increasing the investment in distribution. The solution for reducing distribution cost, therefore, lies very largely in the commercial departments—in the increase in load per customer, and particularly the increase in energy use.

Conclusion

In conclusion, what has been brought out in this paper may be summarized as follows. In the main object of our industry, the giving of good service to our customers, at reasonable cost, distribution has large responsibilities. These responsibilities have been fulfilled in the past by careful attention to engineering details. Means for improving service and for decreasing costs have been developed and applied. The future holds similar problems. The responsibility is recognized. It will be met.

Further Progress in Standardization of Distribution Transformers

THROUGH cooperation of local utilities and geographic organizations, the EEI-NEMA Joint Committee on Standards for Distribution Transformers has presented its First Report at fourteen regional meetings. The latest presentation was at a meeting of the Pacific Coast Electrical Association in Oakland, May 22-24.

At these meetings both engineers and operators have shown much interest in the new Standard and the discussions have indicated a widespread intention to take advantage of the economies and simplification which are offered. One of the features of the meetings has been the opportunity for discussion of specific problems of each group with a view to determining how the new transformer will fulfill the requirements set up by these problems. It is felt that this has done much toward eliminating requirements for special designs which, in turn, aids materially in making available the many benefits of standardization.

As mentioned in the First Report, it was necessary to allow a period of time, following issuance of the Report, for manufacturers to prepare drawings, develop tools and reduce warehouse stocks, July, 1940, being set as the date for initial offerings of the new transformers. Several manufacturers now have the new standard transformers available in certain ratings and it is anticipated

(*Continued on page* 374)

Power Generation Advances During A Depression Decade

By E. L. Hopping

Mechanical Engineer, Philadelphia Electric Company

Address Before the Second Session of the Eighth Annual Convention of the Edison Electric Institute, Atlantic City, N. J., June 4, 1940.

FROM a review of the last eventful decade, sufficient information is at hand to show that utilities have met a 10-year challenge of lower rates, competition and restrictive legislation, by a continued increase in capacity with improved economy in an effort to faithfully serve the nation. Statistics where presented, are not done so for the sake of statistics alone, rather in an endeavor to span the accomplishments of the period portrayed.

A. Statistical Data

Thus the following data is of great significance and provides a background for the forthcoming discussion. The latest Edison Electric Institute statistics are the source for this material. It is a survey of the private utility industry and except for the TVA, Federal projects are not included.

MR. HOPPING

CAPACITY AND OUTPUT

Generation By	*1929*	*1939*
	(Thousands of Kilowatts)	
Steam	21,744	26,732
Water Power	7,438	9,935
Internal Combustion	376	799
Total Installed Plant Capacity	29,558	37,466
Increase in Capacity—26.8%.		
	(Thousands of Kilowatthours)	
Steam	59,128,100	83,093,000
Water Power	30,956,300	39,370,000
Total Generated Output	90,084,400	122,463,000
Increase in Output—35.9%.		

Fig. 1 is diagrammatic of the above.

Building construction, car loadings, and steel production dropped after 1929, and have not recovered the ground lost. Electricity on the other hand, as the statistics show, has far exceeded its 1929 figure.

Although considerably less money was spent on new capacity during the last ten years, compared to the previous ten years, there is no indication of any deficiency in present installed capacity. It is apparent, from an analysis of installed plant capacity and total generated output, that capacity factor, a function of the years' use of installed capacity, which was 34.8 per cent in 1929, has advanced only to 37.3 per cent in 1939. Appreciating that a system load factor of 100 per cent is not within attainment need not preclude generating more kwhrs from existing capacity. Productive capacity is still far from being fully utilized. Prior to 1929 the general electrification of the nation was largely responsible for that period's phenomenal load growth.

CAPITAL INVESTED (IN TOTAL PROPERTY)

1929	*1939*
$11,100,000,000	$12,790,000,000
(15% increase)	

REVENUE

$ 1,938,000,000	$ 2,294,000,000
(18% increase)	

FUEL CONSUMPTION

1.69 lb. per kwhr	1.39 lb. per kwhr
(18% reduction)	

See Fig. 2.

During the last decade the increases realized were through greater sales to existing customers and to those relatively few new industries introduced during the decade. Electricity's and industry's advance of the nineteen twenties was interrupted during the nineteen thirties only in so far as industry was concerned. During this decade of doubt for industry, electricity continued to surge forward.

Fuel consumption, expressed in terms of lbs of coal per kwhr for electric plants indicates that the industry has consistently established new lows throughout the period. A central station rate of 1.69 lb per kwhr in 1929 compared to the present 1.39 lb per kwhr indicates the strides that have been made in economy. Total fuel consumption, however, has been maintained with the increased output of electrical energy. The fuel economy curve is rapidly flattening out. With today's available heat cycles, further reduction becomes more difficult. Some other strategic point of attack, such as for instance, direct conversion of fuel to electrical energy, is required.

A study of combined average hours' use of steam and hydro capacity indicates that the rapid decline, which occurred during the early part of the decade, has been recovered to such an extent, that a comparison of 1929 to 1939 shows an increase from 3048 hours to 3269 hours use of the total capacity.

Extension of hydro capacity and steam

additions, together with those already existing, now total 37,466,000 kw. Recent hydro capacity is net increase and recent steam capacity is practically so. Superposition of existing steam plants has added new capacity and rehabilitated old capacity, creating base load capacity from that which was, in many cases, relegated to peak load service.

A review of energy sales to ultimate consumers indicates the following trends:

	1929	*1939*
	(Millions of Kilowatthours)	
Farm	1,602	3,320
Residential	9,526	19,740
Commercial Small Light & Power	13,106	20,235
Commercial Large Light & Power	42,971	52,773
Municipal Street Lighting	2,038	1,835
Street & Interurban Elec. R. R.	5,049	3,900
Electric R. R.	590	1,847
Miscellaneous	412	2,437
Total	75,294	106,087
	41% increase	

Fig. 3 is diagrammatic of this comparison.

Total ultimate sales of energy indicate an increase of approximately 41 per cent throughout the ten-year period. Farm sales and residential sales more than doubled, only municipal street lighting and street and interurban electric railways show a decline. Most encouraging classification is among the residential and small commercial customer.

The last year was the first to witness total sales to ultimate consumers of over 100,000,000,000 kwhr.

B. Further Statistical Cost Data

Consumer revenue increased from $1,398,000,000 in 1929 to $2,294,000,000 in 1939.

Kwhr unit revenue therefore has dropped from 2.58c ($1,938,000,000 for 75,294,000,000 kwhr) to 2.16c ($2,294,000,000 for 106,087,000,000 kwhr) in 1939.

During the period when sales to ultimate consumers increased 41 per cent, their total electric bill increased only 18 per cent.

Even more enlightening is an investigation of the residence customer's bill. In 1929 his average consumption of kwhr was 499, costing $31.44 per yr or 6.3c. per kwhr. The year 1939 witnessed 890 kwhr sales for $36.05 per yr with a unit rate of 4.03c. The average residential customer has increased his kwhr consumption 80 per cent. The bill for this additional energy has, however, increased only 15 per cent. The unit cost in cents per kwhr is now approximately 64 per cent of its former value of ten years ago. What other commodity can offer a parallel?

Reasons for Advances

These accomplishments have been made possible by many advances and developments in the utility industry. Some of the more important are discussed in the following pages.

During ten years the power plant has witnessed a tremendous increase in operating pressure, temperature and in the capacity of steam generating units. The beginning of the 1930's saw the introduction of 1400 lb steam pressure and the end of the 1930's, the acceptance of steam temperatures as high as 950 F. Steam generators in capacities of 600,000 lb per hr are commonplace and 1,000,000 lb per hr units are in operation. The present shows a definite trend toward the general acceptance of the high-pressure, high-temperature units. Medium capacity steam generators seem to be in the favored majority.

Steam turbine development has advanced with the boiler design both in pressure, temperature and capacity.

These changes of a ten-year period show marked reduction in Btu rates. Prior to the 1930's the best overall plant efficiency was approximately 25 per cent. This efficiency has now been improved to something over 30 per cent. The Port Washington plant which operates on a regenerative—reheating cycle reported a net heat rate of 10,770 Btu per kwhr at 59 per cent load factor for 1939.

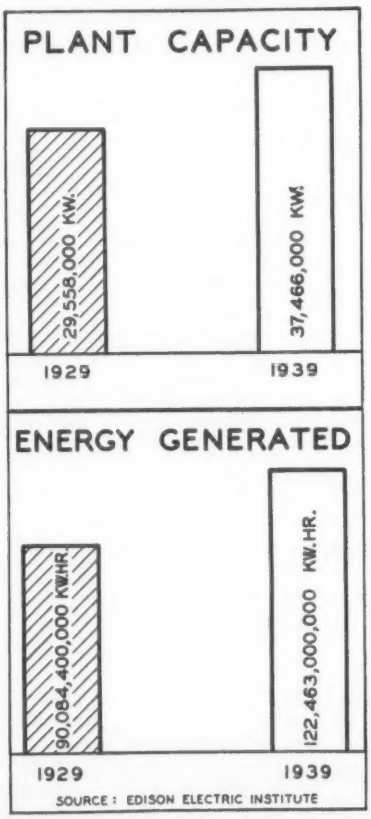


Fig. 1

(a) These tremendous advances have been made possible to a great extent by metallurgical progress. Alloy steels have made possible safe operation with the high-pressure and temperature conditions encountered. In power plant practice carbon-molybdenum steel is standard where the properties of plain carbon steel are inadequate for the service conditions encountered. Laboratory experience indicates good working qualities and satisfactory high-temperature characteristics up to approximately 1000 F. At 1000 F, the creep strength of carbon molybdenum steel is twice that of plain carbon steel, however, further experience at the present maximum of 950 F. is needed before extending the range. When corrosion resistance and further stability is an additional factor, other alloying elements are successfully used.

(b) The use of welded joints for piping and equipment with elimination of flanges and fittings has greatly contributed to the permissible increase in pressures and temperatures. High-pressure and temperature steam piping systems of carbon-molybdenum steel can be readily and economically welded. Welding processes have been developed to such an extent that in many plants high-pressure and high-temperature piping is entirely of welded construction.

(c) Thermodynamic advancements and research have contributed to the development of the heat cycle. Recent cycles show little similarity, particularly in the case of the superposed plant, where in order to make best use of existing equipment, it was impossible to arrange a standardized heat cycle.

(d) Joint research between utility and manufacturer has enabled manufacturers to conduct research problems under actual operating conditions in the utility plants. Conducted independently, the costs would be excessive. When large quantities of steam under high pressure and temperature are necessary to conduct experiments, the utility can provide these and absorb in its system ex-

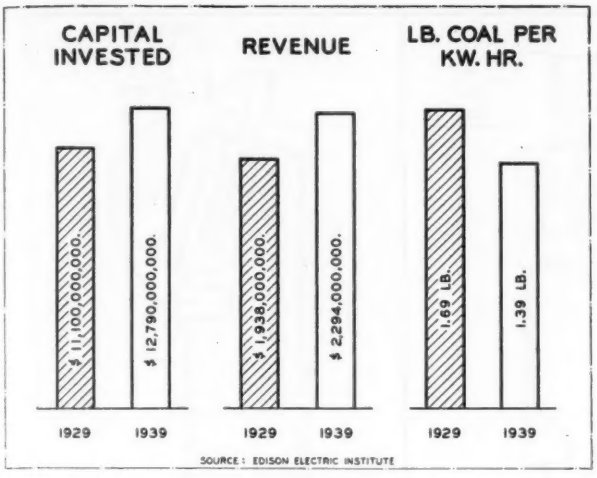


Fig. 2

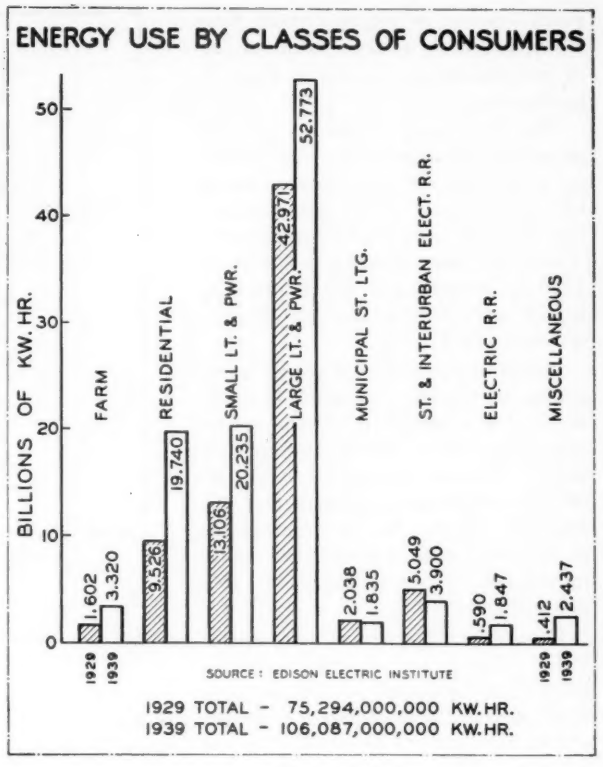


Fig. 3

haust steam and electrical energy. Such research should be encouraged and undoubtedly will prove of mutual benefit to utility, manufacturer, and the customer of both. The installation of a superposed turbine by the Westinghouse Company in the Schuylkill Station of the Philadelphia Electric Company is such an example. This unit, with a full-size impulse wheel of 10,000 kw is running at 1250 lb., 900 F for study of the factors affecting the operation of impulse blading under actual plant conditions.

Any survey of power generation would be incomplete without a tribute to the pioneering research and untiring efforts of the manufacturers in their development of new and improved equipment. In the initial stages of development of any piece of equipment, certain operating difficulties are inevitable, but these have been overcome in most instances through cooperative effort of the purchaser with the manufacturer resulting in an improved design and greater economy.

In the field of power generation, perhaps the greatest contribution toward economy was a reduction in fuel consumption per kwhr. As previously indicated, it is not expected that fuel consumption will be further materially reduced until some fundamental improvement in the heat cycle is made available. Rapid developments in the cycle efficiency or size of the gas turbine, or even direct conversion of energy, are not likely immediately. The present condensing cycle with its inherent heat loss is a field for further investigation. However, the superposed turbine has furnished additional capacity with no increase in condensing requirements. Simplification of plant presents many opportunities.

More factors are influencing the design of plants than ever before and it is not likely that any lessening will occur. The basic problem of plant economy has been well met with fuel consumption reduced. This has been a conspicuous contribution of the past decade. Since fixed costs are a large portion of the total production costs, it is evident that intensive study should be made toward reduction in investment of plant.

Economic problems of power cannot be too greatly stressed. Future plants necessarily must combine low unit cost with high thermal efficiency and availability in order to realize low fixed charges and low operating costs. Economy features in new plant design can only be evaluated in their relation to the entire system through incremental studies on the system as a whole.

Much has been done, more must follow.

Steam Power Plants

During the early part of the decade, design of plants in the high-pressure range had progressed to a considerable extent and the following table shows characteristics of some of the units in operation.

In this group of plants, a temperature of approximately 860 F was the maximum employed. Many used a reheat cycle. These plants, except for the Burlington Station, were not of the "super-

HIGH PRESSURE STEAM PLANTS—MAX. TEMP. 860 F.

Station	*Initial Operation Date*	*Boiler Capacity Lb. Per Hr.*	*Pressure Lb. Per Sq. In.*	*Temperature F.*
Edgar, Boston, Mass.	1925	1—143,000	1,200	700
	1927	2—250,000	1,400	733
	1929	2—300,000	1,400	750
Deepwater, N. J.	1930	4—330,000	1,250	725
		2—290,000		
Deepwater, Tex.	1932	2—375,000	1,350	850
South Amboy, N. J.	1930	3—280,000	1,400	750
Northeast, Mo.	1929	2—230,000	1,275	725
Lakeside, Wis.	1926	1—240,000	1,300	725
	1930	3—250,000	1,300	750
Holland, N. J.	1930	2—250,000	1,400	750
Station A, San Francisco, Calif.	1931	3—500,000	1,250	750
Station B, San Antonio, Tex.	1930	1—215,000	1,325	810
Burlington, N. J.	1932	1—525,000	700	860

posed" variety as we understand them today, inasmuch as their main purpose of installation was not one of plant rehabilitation.

The Deepwater Station, N. J., employed the reheat principle. All six boilers were essentially alike, except that on two of them part of the economizer section had been replaced by heating coils. The boilers were designed to operate at 1250 lb pressure and 725 F; two reheaters were designed for 450 lb pressure and 750 F.

The Burlington Station placed in operation in 1932 was definitely a superposed plant. Design conditions at this plant were 700 lb 860 F, and approximately 200 lb at the exhaust. One 18,000 kw—3600 rpm turbo-generator was installed. During the first half of the decade there were a number of similar installations in the 400-800 lb, 700-860 F range.

Developments in the aforementioned utility plants, and experience gained from large industrial installations similar to that of the Ford Motor Company at Dearborn and the Firestone Tire and Rubber Company at Akron, were forerunners of an era of modern high-pressure, high-temperature installations that we know today. They provided the necessary metallurgical experience and their operating records provided that necessary knowledge of availability which gave confidence for the next step. The logical outcome was the 1,250 lb-900-925 F superposed plants, the first of which were placed in operation in 1937. Among this group were:

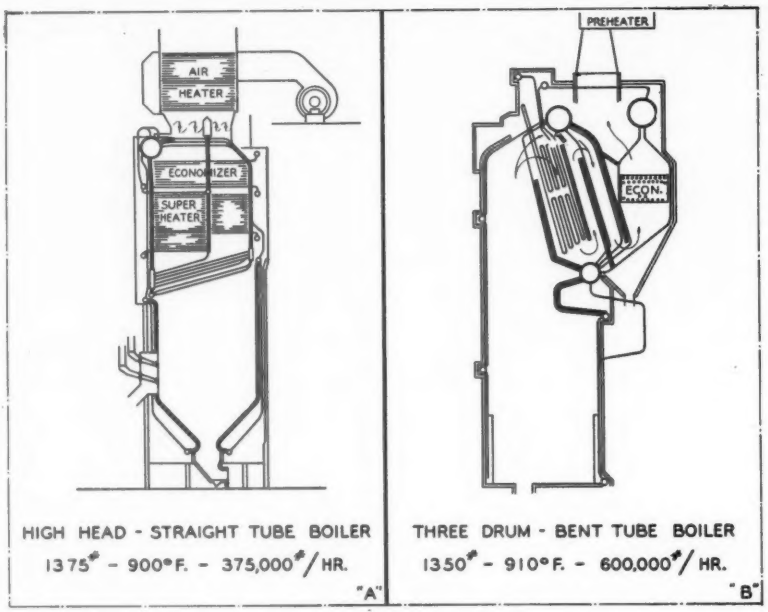


Fig. 4—Sections through Boilers: (A) with Hopper-bottom Furnace; (B) Continuous Slag Tap Furnace

HIGH PRESSURE STEAM PLANTS—SUPERPOSED—900-925 F.

Station	Initial Operation Date	Boiler Capacity Lb. Per Hr.	Pressure Lb. Per Sq. In.	Temperature F.
Logan, W. Va.	1937	1—1,000,000	1,325	925
Waterside, N. Y.	1937	2— 500,000	1,325	900
Millers Ford, Dayton, Ohio	1937	2— 375,000	1,250	900
West End, Cincinnati, Ohio	1937	3— 350,000	1,275	925
Omaha, Neb.	1937	1— 275,000	1,250	910
Rivesville, W. Va.	1937	2— 360,000	1,240	915

A number of other plants were placed in operation during 1938 and 1939, still others are now in process of construction. Thus the modern superposed plant had arrived.

An analysis of new condensing and superposed plants for 1939 indicates a reduction in the latter as compared to 1937. Many of the older 200-250 lb plants have been topped and modernized during the last 3 years. The trend, therefore, has been somewhat retarded inasmuch as many stations already have been topped.

With superposition many plants formerly in the 17,000 Btu to 20,000 Btu per kwhr class have been placed in a base load category rating of approximately 12,000 Btu per kwhr. These figures are subject to variations depending on the design conditions of the older section of the superposed plant and other economic conditions.

A review of steam turbine generators purchased during 1938-1939 also shows some interesting trends in condensing units. The high-pressure 1,250 lb, high-temperature 950 F characteristics have been accepted in this field for the larger condensing capacities.

The largest unit ordered during 1939 was a 100,000 kw machine. It is a cross compound turbine generator and consists of two 50,000 kw identical generators, driven respectively by high-pressure and low-pressure turbine elements, which both operate at 3,600 rpm. Steam conditions are 1,250 lb, 950 F and 1 inch back pressure. The high-pressure element has a single cylinder. The low-pressure element has two double-flow sections in tandem.

Boilers

During the past year, for central station service over 90 steam generating units of 700 lb design capacity or greater were on order or completed, with an aggregate capacity of over 31 million lbs of steam per hr. These requirements indicate the definite trend toward the accepted high pressures and temperatures. Five boiler manufacturers are represented. Lower pressure units, when installed, were used to meet steam conditions in older plants. Eighteen of the steam generators are for new plants, indicating that an era of new plant construction may be approaching. Superposed plants and additions comprise the remainder with a tapering off of superposed units.

The Twin Branch boiler on order for the Indiana & Michigan Electric Company continues to be the outstanding high-pressure 2,500 lb, 940 F unit. This 550,000 lb per hr open-pass type unit was released for fabrication during the past year.

Thirty-three units are in the 1,400-1,500 lb, 26 are in the 800-1,000 lb, and 31 are in the 700-800 lb range. Approximately two-thirds of the units employ

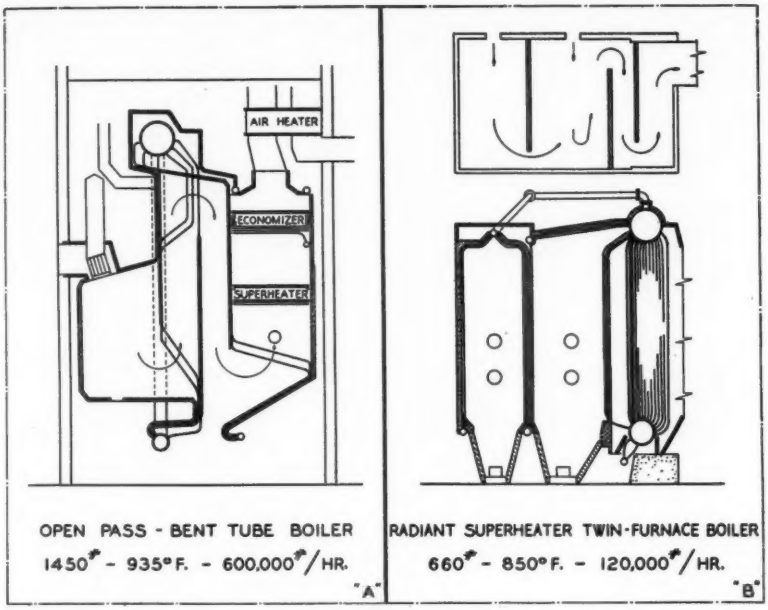


Fig. 5—Sections through Boilers: (A) with Continuous Slagging Furnace; (B) Dry Bottom Furnace

total steam temperatures of 900 F or over. The tendency to higher temperatures is even more evident than the pressure increase. The multi-drum bent tube type has been ordered in the majority of installations. Following these in popularity are the radiant type, two-drum bent tube type, cross drum straight tube and open pass type.

Two-thirds of the new installations are pulverized coal fired, the remainder are either stoker fired or they burn oil or gas. The majority are furnaces of the dry bottom type. The larger steaming capacity units are, however, of the slagging bottom design favoring the continuous drip type against the intermittent type. In this selection, the fluid temperature of the ash in the coal, unit sizes and existing conditions are necessarily determining factors.

Superheat control of the units is primarily by means of by-pass dampers. Excess superheater surface makes it possible to by-pass gases around the superheater to regulate the steam temperature. Only a few units employ desuperheaters. However, it is not unlikely that this method of control may prove most satisfactory and efficient in the light of recent experience with these units.

A representative group of 10 recent large boilers—300,000 lb per hr to 1,000,000 lb per hr—in operation during 1938 indicated that service availability averaged about 80 per cent of the total elapsed time. Single boiler and turbine experience, such as that with the Logan installation, shows encouraging performance.

Removal of slag and ash from water walls and tube surfaces has accounted for the majority of boiler outages. Superheater tube spacing shows a tendency to increase. This eliminates to some extent slagging and clogging tubes with the resultant possibility of overheating and failures.

The most recent tendency does not seem to be toward an increase in steam generating capacity. The Oswego boilers, two 850,000 lb per hr, 1,450 lb, 903 F radiant units, were the largest ordered in 1939. The tendency seems to be toward a consolidation of the advances of the past years.

In the Saskatchewan plant of National Power & Light Co, a 120,000 lb per hr radiant — superheater boiler of two-drum, two-furnace design, is being installed. The two furnaces are separately gas or oil fired, one for steam generation and one for superheat, where by means of firing ratio, temperature control is obtained. This unique boiler is designed for 660 lb and 850 F.

Figures 4 and 5 are representative of certain types of boilers that have been previously referred to.

During the coal strike of 1939, the value of combination coal-oil-gas burners was again demonstrated. Where fuel oil was available, advantage was taken of its use to retard depletion of coal reserves. Rapid conversion of some units to oil firing, during this period, proved expedient. On larger size boiler units, successful operation was experienced burning coal and oil, also oil and natural gas in combination.

Formation of slag on the boiler heating and transfer surfaces, restrictions in circulation and in complete separation of steam and water in the boilers continue to be major problems confronting the manufacturer and operator.

One of the most frequent causes of boiler outage is the necessity of cleaning surfaces of accumulated slag. Mechanical blowers are used extensively. The use of higher pressures for soot blowers, deslaggers and wall cleaning devices continues.

Boiler circulation, having been calculated by the designers, should be immediately checked by the manufacturer upon placing of the steam generating unit in service, particularly where there has been any change in design over one already proven. This should be done to determine whether design conditions have been met. Such a procedure may prevent circulation troubles and loss or reduction in availability of boilers.

Boiler Gage Glasses

The necessity of securing an unobstructed view and the importance of knowing the exact water level in the drum at all times has led to important developments in this field.

The bi-colored glass, based upon an optical principle that the refraction of a ray of light differs as it passes obliquely through different media, such as steam and water, has made possible the projection of the image of the water level to the operating floor. Other arrangements, either by means of targets or remote reading and recording devices, transfer the water level from the boiler drum to the operating floor level. Further research into properties of glass, to withstand the high pressures and temperatures of the steam, is necessary.

Steam Scrubbers

In modern high-pressure and temperature plants, carryover of dissolved solids in the minute water particles in the steam leaving the boiler drum has resulted in deposits in superheater tubes and especially on turbine blades with a resultant turbine capacity decrease. The purification of the steam by means of mechanical devices located in the boiler drum has been the object of extensive study. Separators of the cyclone type, screen type, and bubble type, as well as

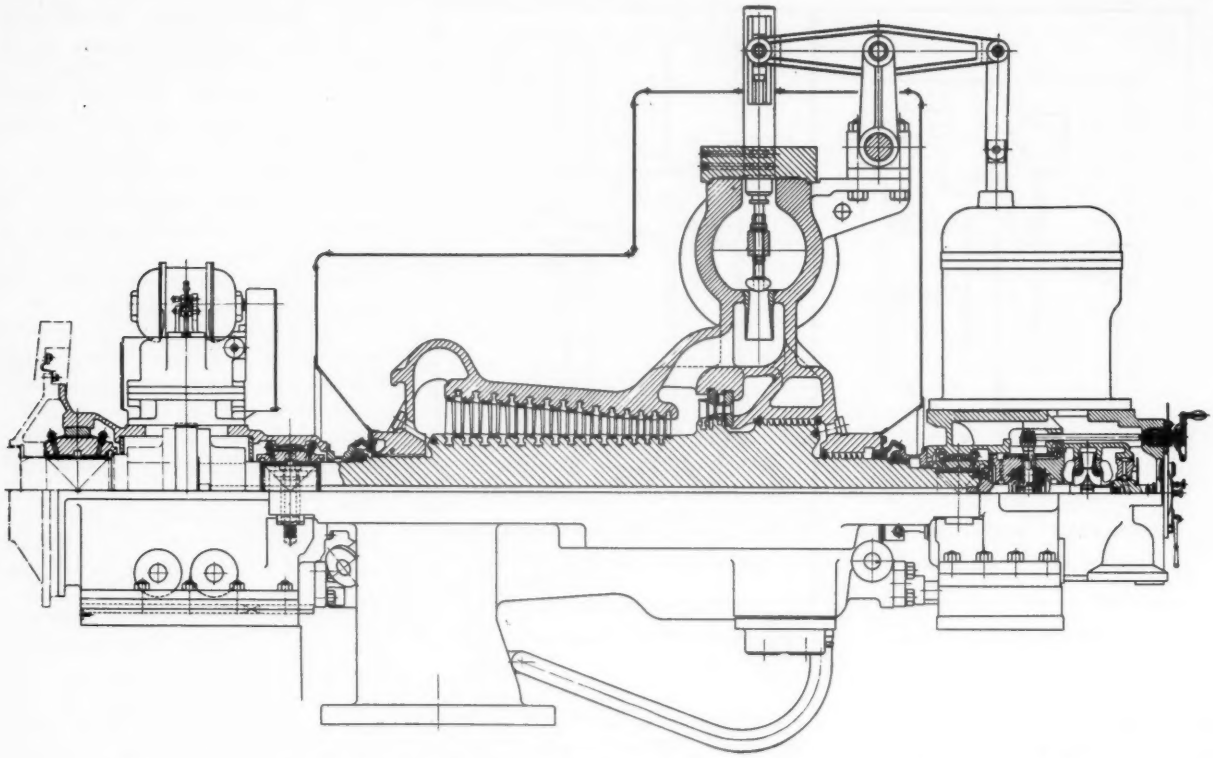


Fig. 6—Cross-section through High-pressure, High-temperature, Single Cylinder Superposed Turbine

various combinations of the above, are in use.

Feedwater

The use of high pressures in boilers has made it particularly important that water conditions be carefully considered. With the high rate of heat input to boiler surfaces, any deposit resulting from improper treatment of the water may cause failure in boiler tubes.

Chemical method for lessening of the total solids is receiving much study. The prevention of scale deposits is receiving more attention and in this connection the elimination of silica from the boiler water is of prime importance. The removal of dissolved oxygen, which even in small quantities causes corrosion of tube surfaces, is being accomplished by thermal deaeration supplemented in some instances by chemical scavengers. With a tendency toward the use of deaerating hot well condensers, it is possible to eliminate the deaerators in the heat cycle. However, considerable research and development is still required to reduce corrosion on boiler tube surfaces.

Collectors and Ash Handling

The elimination of fly-ash from the flue gases has become a problem of ever increasing importance with the pulverized fuel fired plant, and dust collector efficiencies of approximately 90 per cent have been reported. The installation of such equipment is a substantial item in plant investment, however, their use effects some reduction in induced draft fan blading erosion and a corresponding saving in maintenance.

The electric precipitator has provided a highly efficient means of dust elimination. The beginning of the past decade saw its widespread acceptance. During the latter part of the decade the mechanical precipitator of the cyclonic type has competed very strongly with the electrostatic design unit.

Satisfactory disposal of fly-ash and slag is an ever-present problem, particularly where disposal area is limited as is so often the case in metropolitan areas. Generally the slag, because of its greater density, can be easily removed. The fly-ash, on the other hand, because of its greater volume and difficulty in handling, presents a more serious problem. Further study and research are essential. Among the possibilities are:

(1) Introduction of fly-ash into the furnace for disposal as molten slag.
(2) Partial replacement of cement in concrete aggregate.
(3) Disposal to outside industries for manufacture of block tile, etc.

While the above discussion applies principally to pulverized fuel installations, it is realized that removal of cinders from stoker fired boilers is important for metropolitan areas. This is usually accomplished by the mechanical type separator, although in some plants wet type scrubbers have been used.

Mechanical Draft Equipment

The fan manufacturers have kept abreast of the rapid developments of the past 10 years. Fan capacities and particularly fan statics have made tremendous increases. Design of this equipment requires very special care considering particularly that factory tests on fans are in many cases out of the question because of size of units and expense involved. The manufacturer must project his design data to the new conditions. For large boiler installations, two forced and two induced draft fans per boiler have provided a flexible arrangement. With some of these, fans with static pressure in the range of 25 inches of water are on order, which more than doubles the range of ten years ago. In some instances where new equipment is being located in existing plants, the combined forced and induced draft fan unit has proved most economical. High speeds

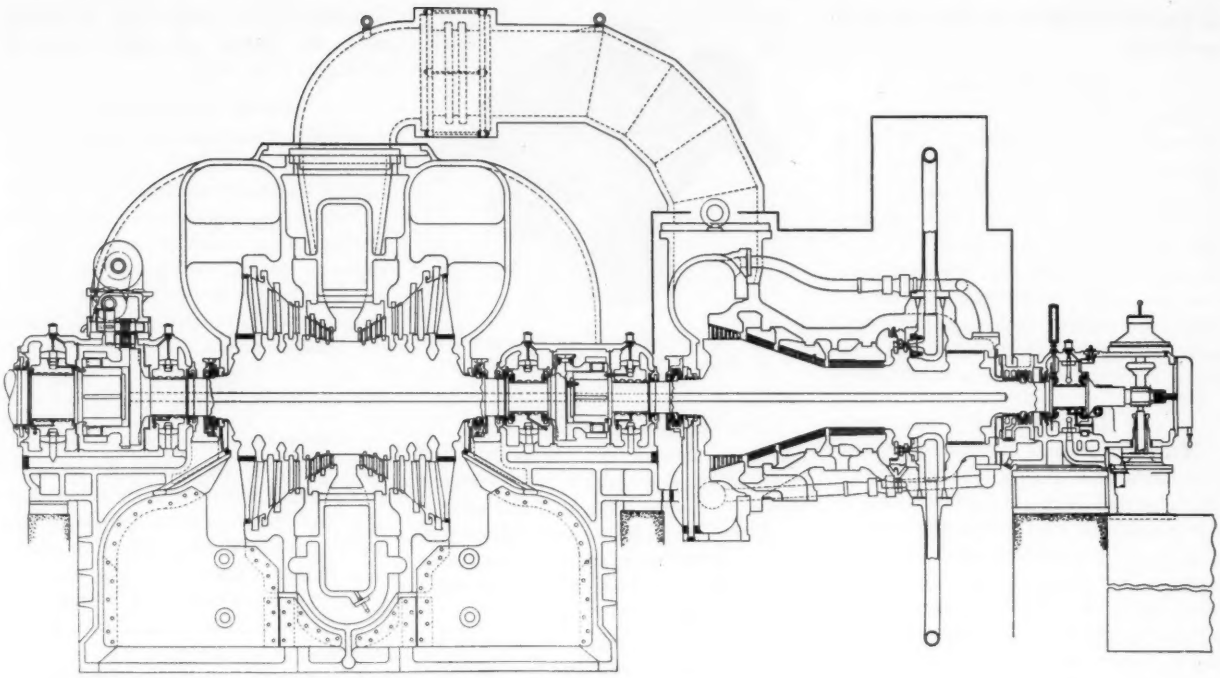


Fig. 7—Cross-section through High-pressure, High-temperature, Tandem Compound, Double Flow Condensing Unit

of fans, greatly increasing erosion of the blades when dust or cinders are encountered, has resulted in careful investigation of fan location, particularly in relation to the dust collector.

In a search for economy and flexibility the fan control problem has been given much thought. Constant speed motor drives with vane or hydraulic coupling control predominate on large units. The oil controlled hydraulic coupling introduced during the decade has provided an efficient method for infinite speed control. The more recent magnetic drives, with their wide range and closely adjusted speed control, offer further possibilities. A healthy competitive condition exists in this field.

Steam Turbines

The principle advances in steam turbine generator design, during the past ten years, have been size of units, higher speeds, hydrogen cooling, and increased economy because of higher pressure and temperature. Detail improvement in turbine construction has taken place particularly with fabricated steel, protection of turbine blade edges from erosion by use of high resistant metal alloy and increase in separation of moisture between turbine stages.

During the early part of the period, cross-compound multiple units with capacities up to 208,000 kw, tandem compound, single shaft units as large as 165,000 kw, and vertical compound, two shaft units of 110,000 kw were installed. The 208,000 kw machine comprised three generators and the 110,000 kw machine, two generators.

Recent surveys indicate that for condensing operation in the 3,600 rpm class, present designs permit about 25,000 kw in single cylinder turbines and about 50,000 kw in the two-cylinder tandem type. In the 1,800 rpm class these limits are about 100,000 kw for single cylinder and about 200,000 kw for tandem arrangements. For superposition application 3,600 rpm, the 75,000 kw back-pressure unit seems practicable. All the abovementioned types are single shaft machines and drive a single generator. These figures are very general however.

The largest 3,600 rpm superposed turbine in service was 53,000 kw with 65,000 kw on order. A feature incorporated in some of the larger capacity units of this type consists in partially by-passing the second and third stages after the steam has passed through the first wheel. Higher capacities are obtained in this way. The double shell construction has been incorporated on a number of units, some already in operation and others under construction.

During the latter part of the period when some impulse blade failures occurred on a few units, the impulse blades were moved and the turbines carried from 80 to 100 per cent on the reaction blading alone. The entire subject of impulse blading operating under high pressure and temperature is a subject of intense investigation and it is expected that much benefit will derive from the work that is taking place.

A cross-compound machine for the Twin Branch Station, previously mentioned under boilers, is on order. The high-pressure element has a single cylinder with a double shell, rated 22,500 kw, 0.8 pf, 28,125 kva, with hydrogen cooling and 3,600 rpm. Throttle steam conditions are 2,300 lb gauge, 940 F, and the exhaust pressure is 445 lb gauge. This installation should prove another noteworthy pioneer.

During the latter part of the decade, from 1937 on, the 1,200 lb, 900 F, 3,600 rpm turbine was generally introduced. Maximum operating inlet conditions at present are 1,250 lb and 950 F. The history of the increase in pressure and temperature is generally similar to that of the boiler. It is believed that progress toward any higher temperatures of turbines will be retarded somewhat. Further knowledge is needed, particularly regarding the characteristics of materials under the higher temperature before the temperature range is advanced.

Figures 6, 7 and 8 are representative

of types of turbines that were previously mentioned.

Turbine Instruments

Supervisory control instruments are becoming a more necessary part of the turbine ensemble. Generally accepted is the speed recorder which consists of a shaft-mounted generator which indicates and records the turbine speed. This instrument is most valuable when comparisons are made from records with the other instruments, such as bearing temperature alarms, vibration recorders, eccentricity recorders and sound indicators.

Hydrogen Cooling

Hydrogen cooling of turbo-generators was introduced during the last 3 years of the period with considerable success. Air previously constituted the cooling medium for large generators. In the attempts to increase output per unit of materials used, the 3,600 rpm turbo-generator was perfected. Further economies could be obtained with a more perfect cooling medium. Hydrogen offered, among others, the following advantages:

1. Reduced windage and less noise—increased efficiency.
2. Cleanliness.
3. Improved thermal conductivity and heat transfer.
4. Increased life of windings and insulation.

The experience gained with hydrogen cooled frequency converters and synchronous condensers has been successfully applied to the turbo-generator.

Explosion dangers are eliminated by maintaining a proper and preferably high mixture of hydrogen to air—98 per cent to 99 per cent. Generator casings are designed to withstand explosion. With loss of hydrogen, the units can be run with air at approximately 70 per cent capacity.

Further economies are possible with the increased pressure of the cooling medium. It is expected that increased capacity of 15 per cent may be obtained when the hydrogen pressure is 15 lbs. It is necessary that the hydrogen system be arranged for this pressure.

The Mercury Boiler

Operation of binary vapor cycle plants is not as economically attractive today as in the past because their economy is rapidly being approached by high-pressure, high-temperature steam plants. The mercury vapor plant is capable of producing a kwhr of energy for about 9,500 Btu as compared to the most recent best figure of 10,770 Btu for the Port Washington steam station.

Fig. 8—Double Shell Construction Used on some High-pressure Turbines

With the mercury vapor cycle, the mercury vapor leaves the boilers and passes through a turbine. The exhaust mercury vapor is condensed and returns to the boiler. The mercury vapor condenser acts as an evaporator, producing steam which in turn is used to drive steam turbines.

It is reported that the 10,000 kw Hartford boiler continues in operation at a very high capacity factor, and that the 20,000 kw boilers at Kearny and Schenectady have been operating successfully during the past year. Continued research and development is taking place however, and the General Electric Company is further experimenting with the smaller 1,000 kw mercury units at their Pittsfield and Lynn Works.

Condensing Equipment

Refinement in design of condensers has constituted the advances in this field. Condensers are primarily of one or two pass design, depending on the quantity of cooling water available. Greater quantities of cooling water must necessarily be provided with single-pass units. Considerable saving of floor space has been effected with the use of vertical circulating pumps which have the additional advantage of being submerged, thereby eliminating the necessity of priming. For this purpose, propeller type or modifications of that type are in general use.

Better steam laning of the condenser tubes has been a decided factor in the increase of condenser capacity.

Generally, reheating and deaeration of condensate is provided for in the hotwell. Cast iron shells have been replaced with welded steel plate construction.

Prevention of deposit and algae on the inside of condenser tubes, interfering with heat transfer, has been accomplished by chlorination. Chlorine gas, dissolved in water, is injected in solution into the circulating water. This process may be intermittent or continuous, depending upon the degree of algae formation throughout the year.

Foreign Developments

Simplified turbines and condenser arrangements have been reported on in foreign installations. In one, part of the condenser casing is cast integral with the turbine casing, with the tubes at right angles to the turbine rotor. The exhaust steam leaves the last stage of the turbine and is divided into two paths and enters the condenser over approximately half its length. Simplification of equipment and auxiliaries features this layout.

Comparisons with British Stations

A review of operation and generation of electricity in Great Britain brings to light some interesting comparisons. For the year 1938 Battersea Station (London Power Company, Ltd) sent out 1,152,595,797 kwhrs with a maximum of 232,400 kw. This station was credited with the lowest average fuel consumption, 0.90 lb per kwhr with 13,750 Btu per lb coal, 27.63 per cent thermal efficiency, and 56.6 per cent load factor.

Dunston "B" Station (Northeastern Electric Supply Company, Ltd) had the highest thermal efficiency, 27.85 per cent. The sendout there was 731,587,450 kwhrs, a maximum load of 140,600 kw with a load factor of 59.4 per cent. The average fuel consumption was 1.11 lb per kwhr, burning a lower grade fuel.

These two aforementioned stations led all others in Great Britain in lowest fuel consumption and highest thermal efficiency.

Over a 10-year period, the Deepwater Station, N J, operated with a thermal efficiency of from 28 to 29 per cent. Annual load factors ranged from 73 to 84 per cent. The Port Washington Station previously cited had a heat rate for the year 1939 of 10,770 Btu per kwhr at a 59 per cent load factor. The thermal efficiency was 31.6 per cent.

The Combustion Gas Turbine

The advantages of the gas turbine have been long considered, however, metallurgical problems and the lack of an adequate compressor were until recently retardents to the development of the cycle. The modern unit consists generally of a turbine directly coupled to a multi-stage axial compressor. Air from the atmosphere enters the compressor where its pressure is raised. Part of the air discharged from the compressor is used for combustion purposes, the remaining air cooling the products of com-

bustion to a satisfactory turbine inlet temperature. The gas, a mixture of air and combustion products, then expands through the turbine to exhaust. The power developed by the turbine is greater than that required by the compressor and the excess power is supplied to the generator.

This simplified cycle can be located practically anywhere since its working medium is air. Water sites are not required.

Recent tests reported by Messrs Brown, Boveri & Company, Ltd, of Baden, Switzerland, on a 4,000 kw, 3,000 rpm set indicates a thermal efficiency of 17.38 per cent which, as the author points out, could be increased if an air preheater or an exhaust steam turbine were incorporated.

The gas turbine has attractive possibilities, but it is not considered immediately as a serious competitor of the steam turbine for central station use.

Forced Circulation Boilers

Sufficient advantages have not been apparent to American engineers to warrant installations of boilers of this type in American power plant practice. Their use has been confined to European countries, particularly England and the Continent. With the forced circulation boiler, water and steam are pumped through the tubes instead of depending on natural circulation as is now our general practice. Complications in control and increased power and pumping requirements, so far have tended to offset any apparent economic advantages. It is understood that one of the principal difficulties is in maintaining reasonably tight seals on the pumping equipment.

It is reported that installed or under construction in England are 15 boilers of the LaMont type, 5 Sulzer, 4 Loeffler and 1 Velox unit.

However, the forced circulation type of boilers are not in any sense being overlooked, rather their use is being actively studied by our engineers.

Conclusions

Those identified with, and those served by the power industry, can look forward with confidence to further improvements in operating economy and also to reductions in capital expenditures for power producing installations.

Because of continued change and improvement in the art of power generation, with new and untried equipment, we must be prepared to encounter some difficulties. In the early operation of new equipment, problems are to be expected inasmuch as manufacturers are not in a position to conduct large scale experiments in their own plants. We predict with confidence that in the future as in the past, difficulties that do arise will be satisfactorily corrected.

From the foregoing discussion, it is evident that the science of power generation has experienced no retrenchment during a depression decade in which business generally was retarded. In spite of ever present uncertainties, the power industry and its representatives continued and will continue their forward thinking and acting attitude.

Power Generation Advances During a Depression Decade

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Edward W. Lloyd

EDWARD W. LLOYD, vice-president in charge of sales for Commonwealth Edison Company, Chicago, died on June 26 at the age of 68. He had been in ill health for several months.

Mr. Lloyd was nationally prominent in the electrical industry for his contributions to the commercial phases of the business, including electric service rate structures. He was president of the National Electric Light Association in 1915-16 and headed several important committees in that organization and the Edison Electric Institute which succeeded it.

Born in Belleville, Ontario, on February 3, 1872, Mr. Lloyd was educated in the public schools of that city. In 1880 his family moved to Erie, Pennsylvania, where he later worked in a machine shop and attended high school at night. Coming to Chicago in 1892, Mr. Lloyd entered the employ of the then Chicago Edison Company the following year as a mechanical draftsman. He became a construction foreman in 1898 and four years later was elevated to Assistant Superintendent of Construction. Mr. Lloyd was appointed general contract agent in 1906 and was elected vice-president of Commonwealth Edison Company in 1926.

Serving as chairman of the national committee which planned and directed the electric light and power industry's "Electricity at Work" exhibit at A Century of Progress exposition in 1933-34, Mr. Lloyd also headed the World's Fair electrical committee. In 1922 he was chairman of the Joint Committee for Business Development sponsored by nine electrical societies of the United States and Canada.

A pamphlet written by Mr. Lloyd in 1906 on "Purchased Electric Power in Factories" outlined for the first time in convenient form the approximate amount of power required to drive various types of machines. This provided data which even manufacturers had only partially available and represented a distinct forward step in the sale of electric power for industrial use.

Mr. Lloyd was president of the Chicago Lighting Institute and had previously served in the same capacity with the Electric Association of Chicago.

Covered Neutral Cable Still Helps Sell Adequate Wiring

THE use and promotion of Covered Neutral Cable (CNX) were discussed at the meeting of the EEI General Sales Committee at Atlantic City on June 3. Representatives of the Wiring Committee, of which Mr. E. A. Brand, Buffalo, Niagara and Eastern Power Corporation, is chairman, outlined the present attitude of the Underwriters Laboratories and leading cable manufacturers on the question. Subsequently a statement of progress in introducing the use of this cable was sent to all member companies of the Institute.

Member companies have also been asked by the Wiring Committee to furnish data on their success during 1939 and 1940 in getting Covered Neutral Cable used locally. Mr. Brand's letter requesting this data, which includes information of general interest, is reproduced here.

"Since the first survey of the use of covered neutral ("CNX" or "LCX") cable was made by the Wiring Committee early in 1939 (resulting in information on over 6,000 installations), many utilities have accelerated their efforts to obtain more widespread acceptance and use of this material. The Institute has provided the personal assistance of Mr. Henry J. Morton to utilities, and has made available the promotional booklet, *Covered Neutral Cable Helps Sell Adequate Wiring.*

Additional Promotional Material in Preparation

"To further aid your efforts, a set of attractive Kodachrome slides with an appropriate script for dramatized presentation of the benefits of using covered neutral cable for obtaining more adequate home wiring is in preparation by your Committee and will be available at an early date. This will be a valuable additional sales tool for stimulating contractors and the public to take full advantage of covered neutral cable.

New Survey Data Needed

"Your Wiring Committee now feels that an up-to-date survey of the progress that has been achieved in the territories served by each utility will be helpful in providing you with further assistance. We ask, therefore, that you please answer the questions which are listed on the attached sheet and return it as early as convenient to Mr. G. W. Hart, Ebasco Services Incorporated, 2 Rector Street, New York, N. Y.

Status of CNX Remains Unchanged

"Sufficient acceptance of CNX has been achieved so that National Electrical Code recognition came within two votes (of the necessary two-thirds) of being attained at the meeting of the Electrical Commitee, NFPA, in December, 1939. The fact that so large a majority of the Committee voted favorably is encouraging and speaks well for the trial installation record to date.

"Contrary to rumors which may have reached you, the status of covered neutral cable remains unchanged. It may be installed now under exactly the same conditions as have prevailed since its introduction, namely, with the approval of local inspection authorities. As indicated by copy of a letter from the President of Underwriters Laboratories which follows; no action was taken at the Electrical Committee meeting which affected the Laboratories' attitude toward the cable.

> Dear Mr. Brand:
>
> Acknowledging your inquiry of April 5, you will recall there was no action taken at the meeting of the Electrical Committee last December withdrawing the resolution on record concerning trial installations. Underwriters' Laboratories has, therefore, assumed that the whole matter of trial installation cable, concerning which you inquire, remains in status quo. Accordingly, the special listing and label service that has heretofore been available is to be continued without interruption in so far as it is called for by manufacturers of the cable.
>
> Cordially,
>
> /s/ A. R. SMALL
> President

Availability of CNX

"Several leading cable manufacturers, including General Electric Company and Triangle Conduit & Cable Company, assure us that CNX will continue to be available. We are advised that jobbers will probably not carry it in stock until local demands are felt. We have been assured, however, that it will be available through the respective factories. Thus the probable delay in obtaining supplies should be anticipated. and when arrangements have been made for its local use, steps should be taken to see that it is available for contractors.

"We hope that the above facts with respect to progress in the use of covered neutral will help to stimulate your continued active interest in the promotion of use of the material. Your active cooperation in making this an industry-wide effort is urged.

"We look forward to your survey data and assure you that the Committee will be glad to get whatever additional ideas and suggestions you may care to offer."

Utah Power and Light Wins Award for Annual Report

THE Utah Power and Light Company has won first prize in a national contest for the best illustrated and humanized annual report of an electric utility company for the year 1939, it was announced recently by Reddy Kilowatt Service, sponsors of the contest. A plaque commemorating the award has been presented to the winner.

Honorable mention in the contest was awarded the Iowa Electric Light and Power Company, Cedar Rapids, Iowa.

In announcing the awards Mr. Merryle S. Rukeyser, financial writer for International News Service, who judged the entries, said:

"I award the prize to the Utah Power and Light Company for its annual report for 1939, which has combined simplicity of language with a highly interesting presentation of ideas through the use of Reddy Kilowatt and other cartoon symbols. This company has also used modern concepts for simplifying, streamlining and shortening its income statement.

"I suggest that we also give honorable mention to the Iowa Electric Light and Power Company for its annual report for 1939. The character of the printing and paper, charts and use of language are notably excellent. The company has wisely included in its report to stockholders material relating to its advertising and merchandising."

The Rights of the Eye

By Hugh Grant Rowell, M. D.

General Adviser and Assistant Professor of Education, Physician to the Horace Mann School, Teachers College, Columbia University

Address before the Fourth Session of the Eighth Annual Convention of the Edison Electric Institute, Atlantic City, N. J., June 5, 1940

FUNDAMENTALLY the rights of the eye in modern life are the same as those of an individual—the right to take a place in the world's work commensurate with the best possible contribution the individual (or the eye) can make. It is my privilege today to suggest to you a few things based on my own observations as a medical man and educator who has a deep and sincere interest in better seeing.

I have long been aware of your contribution to the picture of the conservation of vision. My own life, in addition to any professional points of view, has, for various reasons, been influenced by business experiences and friendships and I feel that, because of these experiences and friendships, you and I will be able to realize that we are considering the "Rights of the Eye" as cooperators, interested in the same goals, though approaching them via different but related pathways.

For myself, I am not an eyesight specialist nor even an expert in physiological optics. Nor do I belong to a propaganda group promoting anything in connection with the eye or anything else. In line of duty I have had to interest myself in better seeing and I might add that I have derived both satisfaction and value from so doing.

A myope myself, I learned in elementary school the miraculous difference between trying to learn with a partially efficient eye and what the world—and the blackboard—had to tell me when I could see properly.

Education appealed to me and, when my medical school work and hospital internship were completed, I found myself in charge of the health—and ocular welfare—of some 25,000 school children. Eyes, I learned, were a potent channel for learning. But these same eyes were being neglected and even abused—though with the best of intentions. Some years later I learned from your great scientist, Matthew Luckiesch, that eyes, biologically, had just come indoors. I found as I followed the trail that, both in Europe and this country, studious physicians had tried to make the laymen aware that, apparently, with each year of progress of a child along educational pathways, he paid a price in vision more often than not. The same seemed to be the story in certain types of work in industry. I found, too, that certain children required a special kind of physical set-up for education which we called the "sight-saving class." It was quite a revelation—and to a constructively minded person a most impressive and disconcerting one.

DR. ROWELL

Early in my professional career as what I call an "educational pediatrician," I learned that the success of any movement for conservation or anything else is dependent upon cooperation, usually upon a wide front. In those days, as far as I know, your own group had not been stirred to your present constructive and valuable interest. The interest, anyway, was among such pioneers as Drs. Edward Jackson and John M. Wheeler, among educators sporadically, and the National Society for the Prevention of Blindness which was struggling mightily to rouse us all from our slumbers.

I was invited to Teachers College, Columbia University, to take charge of the health of a group of valuable, even brilliant children who have since proved their worth in the world, outside and inside educational cloisters. They had the best of medical care of every sort, provided through their own family purses. We set up what we considered a high degree of protection for them—from accident and what not. Yet it was evident that eyes were still suffering. And the trail led at once to illumination. I found my colleagues interested in the problem—philosophers, psychologists, teachers, administrators—recognizing that conservation of the child, including his vision, was important to learning.

The trail has led in many different directions. Balanced lighting aided some of our problems. The newer and simpler types of indirect units provided the kind of illumination that neither Nature nor man had been able to give previously. Venetian blinds proved their efficiency for controlling daylight. I have always wanted to experiment similarly with louvres. Double shades and diffusing materials for them revealed good and bad points.

We found that in making rough tests of vision for screening purposes, illumination was the thing on which the test rose and fell. And, when helping to train field units for the American Child Health Association, we went to great effort to devise a special equipment which assured us the necessary 10 to 12 foot-candles on the chart for each child that was tested. In those days it took considerable ingenuity.

Posture or body mechanics has always been a problem in schools. The squirming child may have had a badly designed seat—and most of them are exactly that. But, along with others, I was not too long in realizing that the eye will sacrifice anything to meeting its illumination

needs. And so came a period of studying the relationship between school seating and school illumination—with a recognition that both body and spirit paid a price for our failure to meet this obvious problem.

The lightmeter came into the picture—simple, so easy to understand that we have been able to have young children use it and demonstrate it to their parents. To me, the invention of the lightmeter was perhaps as great a step in the interests of humanity as the discovery of digitalis, morphia and other great and invaluable drugs. From the lightmeter, and from other observations, we learned that the five adjustment school desk, which met all instead of part of the requirements for a hygienic place to read and write, approached our needed answer to posture and behavior problems. Alas, as I shall amplify later, neither of these great inventions has met the interest and use it deserves.

The lightmeter opened up whole new thought in education and industry. Combined with the Luckiesch-Moss Visibility Meter, we had a means of analyzing the illumination needs for any piece of eye work for any eye. Yet how much have we used it? I have gone so far as to set up classrooms "by the meter" as I call it, finding out what the individual lighting requirements were and placing the children in seats and illumination of the right sort to meet them.

Into the home the work went, because a school is only as successful in anything as cooperation of the home permits. My own home became a bit of an experiment station for a while.

All the while the science of refraction of the eye became more exact and America took the lead in this field—which, even now, however, has not resulted in every child that needs glasses securing them or even wearing them when secured.

As the movement grew, the story was presented to the public in better ways. Mistakes were made. Apprehensions were aroused unnecessarily, as in the case of all pioneering, especially when human health and happiness are involved. And the public will always interest itself least and last in the less dramatic and more solid things of life.

From a business point of view, the movement revealed the need of certain services and products, thereby offering the pleasing combination of combining profit and good works. On occasion the profit element came too much to the fore, but that stage was soon passed and the work came upon more solid ground.

Today we recognize a widespread program, on a long-range basis, involving the cooperation of many business and professional groups, with the objective the conservation of vision. Since I have had an opportunity for nearly 20 years to follow the development of the work, it may be that I am in a position to make a few suggestions about its future. It is my sincere hope that both in line-of-duty and leisure I shall have further opportunity to cooperate with, and perhaps even contribute a bit to this splendid Better Light-Better Sight movement.

Our program is one affecting all mankind. It must be audited from that point of view and its future must be planned on such a basis. And because man is thoroughly fed up with propaganda today, our future planning must be along very solid lines in which service will be stressed and the cards put on the table. Our program deals with valuable essentials. We must plan its future with this recognition. To me the facts seem to indicate that the Better Light-Better Sight movement has important and essential social values and, as long as properly conducted, it should serve as a practical means of aiding the physician and educator toward effectiveness in their own part of the program for conservation of vision.

Our job at the moment is to analyze our program, determine our satisfaction with each and every phase, try to determine trends for the future and call upon our scientists to aid us in providing the information and means for reaching our goals. And our goals will, when summarized, all add up to making the eye of every man, woman and child as effective as possible in modern civilization. The eye changes, civilization and its demands change, and so our program must change, too.

What are our present needs?

The first need of the eye is, perhaps, protection from adventitious damage. In recent years we have been able, in the main, to drive from the market, toys which were potential weapons for blinding. Yet the Fourth of July is coming and certain children are going to pay dearly for the dubious privilege of spending their pennies in explosive noise makers. Great credit is due the National Society for the Prevention of Blindness for its pioneer work along this line. The newer safety groups and movements are carrying the work to a broader and even stronger effectiveness. But there is not the slightest doubt that the Better Light-Better Sight Movement must give consideration and cooperation to every thought of protecting the eye from injury from any source. And your strength lies in the fact that, in this movement, industry, the professions and the layman unite on a common problem.

The second need of the eye is expert care. The primary basis of expert care is an audit at regular intervals which, I believe, on this basis of personal experience plus my interpretation of the experience of others, to be at least once a year in apparently normal individuals, especially during the years of growth.

The screening system in the schools, if it were properly planned and conducted, would be adequate for this purpose. However, there seems to be no standardization of testing technique nor recording results. Hence no one can tell us accurately just what problem is present. Since, under the present system, by no means all screened cases receive the expected expert check-ups as by refraction, I am coming more and more to the belief that class room failure is telling us more about children than the examinations of the health office. If this be true, then the children who are successful in the classroom, in spite of impaired vision, are the ones to suffer. There has been a tendency of recent years to try to bury the gifted child in a mechanized educational program and his eyes as well as his mind may be paying the price.

The answer lies in the development of an acceptable and accepted technique of school eye testing, in detail, and seeing that it is carried out. Only cooperation secured through educational measures is going to accomplish this. The failure of audiometer laws is my proof.

I might add that school budgets are never going to permit annual testing by eye specialists of every pupil. Let us, instead, advocate something which can actually be done. Perhaps the testing might be done under the supervision of an eyesight specialist. But the main thing is a simple test, with the letters or other visibles under proper illumination, which I am convinced is 10 to 12 footcandles as revealed by the lightmeter for this particular purpose.

The third need of the eye is use under proper conditions. Here again I charge neglect. The lightmeter as the key to proper illumination has never attained as much use or service as it de-

serves. Our information is that there are in the neighborhood of 20,000 of these small lightmeters in use and these are almost exclusively in the hands of salespeople of utilities and lighting equipment manufacturers. A wide distribution of the meter would be most desirable, so that all commercial and industrial institutions, schools, etc., would have one available. In other words 2,000,000 of them should be in use instead of 20,000. The Luckiesch-Moss Visibility Meter, in my hands, at any rate, revealed invaluable information regarding practical and individual eye hygiene. As stated earlier, you can, if you will, arrange a classroom with the aid of the lightmeter and visibility meter in such a manner as to give every pair of eyes a maximum chance for good hygiene.

Even with general standards of lighting maintained, we may not forget that the needs of individual eyes vary widely. It is well known that a myope requires more light than a normal eye. I happen to be a myope myself and my desire for more light is a subject of considerable discussion in our home.

All of us in the educational field have fought the problem of the classroom without daylight. Yet unless teachers are willing to spend the time to properly use the shades or Venetian blinds and unless school administrators insist that proper lighting is as important as any other educational service, there is nothing to do but take out the windows and set up something that is going to give the eye a break. Since this cannot be afforded, chaos is the result and eyes suffer.

In planning the illumination of classrooms you must forget about engineering tricks and get down to simple things available at low cost of operation and installation. There is no sense in delivering 50 footcandles under conditions which heat and dry the room to the point of torture. Yet I have found this done. I don't know who is to blame, but engineer and manufacturer must meet this situation more adequately. Parenthetically, many educators are hostile to indirect units because of the cleaning service required. It is a thought for you.

I have always wanted individual lights on school desks. It is the answer and it is not impossible. But we may never get it. We talk about the rights and privileges of the individual and then mechanize and standardize to the limit. Indeed one trouble about society today in general is that it is absolutely inconsistent, stating one thing and doing the opposite.

Strangely, a teacher will, on occasion, take great delight in some unsymmetrical plan of placing the seats in a classroom but there is no romance in merely doing the chore of controlling the sunlight by proper use of the shades. When the normal schools take up this matter, we may get somewhere. Educators today are stressing the thought that the teacher's job is far more than the older concept of "teaching" in the narrow sense.

In your Better Light-Better Sight program, you must make good lighting vital to the teacher—and you must not confine your suggestions to artificial lighting. Photocell control would help but it has never been properly promoted. I can't understand why. Why not take it out of the laboratories into real life?

You have had better success in the home than in the school. I am unfamiliar with the industrial angles and will not discuss them except to remind you that here, too, eyesight conservation and human health and happiness are inevitably linked.

Homes, today, are being educated to better illumination. The problem, of course, is combining illumination with decorative values. But, to speak bluntly, I wonder if there has been much further advance from the manufacturing point of view than what has been accomplished by the IES specification lamps. Decorators too often sacrifice illumination to appearance, and cheeks fading with the years look better under soft and dim lights even if one cannot read the menu or anything else under the circumstances. Perhaps then, not lethargy of the manufacturer but man's desire to put his best foot (and complexion) forward, is to blame.

But in the home, at least, we ought to expect proper lights for safety and for reading, properly placed to look well and serve well. I pay a great tribute to your home service ladies for rendering real service to society and to eyes. And if the industry, in all its branches, has profited thereby, you may well sit back comfortably and feel that this is your reward for recognizing a real social need and supplying it. But alas, I cannot find a fixture for my own dining room which will get me the result I want. The most promising candidate was in a railroad dining car and the cost about five hundred dollars. So there is still opportunity for thinking along constructive, as well as decorative lines, in the designing and manufacturing of lumenaries. I still hope to get the right light. I have faith.

One of your most difficult problems is that the basis of your program is industrial. We laymen have become allergic to almost any kind of a campaign today, having suffered mightily from them. The newer trend which I am told is coming into advertising, namely, simply tell your story in understandable language, will help you in wider acceptance of your program—a program which can and should be recognized as a community service. Indeed the minute you make it anything else, you will cease to secure results from it. You can never be in a position of "everything to give and nothing to sell," but I question if this campaign, a community service, is not your best and most painless salesman, provided genuinely good public relations are maintained by your executives and employees.

You have, in your Better Light-Better Sight program, experimented with decentralization through local councils. I believe this is wise if an assured central policy is maintained.

Finally, may I recall to you the necessity of retaining whatever strategic position this situation may be in. Every day, almost, a new generation rises, to be retaught, to be trained along protective lines of the current year and not of even the previous year. No program, which plans to last, can afford to leave its bases unguarded, to launch off in some new phase or direction exclusively. And so, despite the success the Better Light-Better Sight program has had, you cannot afford to let it get away from its fundamental basis, perennially maintaining a desirable point of view regarding the conservation of vision in a changing society and changing generations. In other words, you may wish to do more, but you cannot do less and expect results. By you, I mean all individuals and groups concerned in this cooperative program. Nor may you neglect the research which brings your problem of tomorrow.

To summarize, your Better Light-Better Sight program may be considered as a cooperation between several industries and professions and the community. The community profits in that the eye gets its rights. You profit because you are able to supply, at a reasonable cost, those things which are physically essential to securing the rights of the eye for

(*Continued on page* 374)

An Approach to the Development of the Commercial and Industrial Markets

By George W. Ousler

General Sales Manager, Duquesne Light Company

Address Before the Second Session of the Eighth Annual Convention of the Edison Electric Institute, Atlantic City, N. J., June 4, 1940.

THE development of the Commercial and Industrial Markets in a territory served by any utility offers some very interesting possibilities. After giving careful consideration as to the comments I might make on this subject, I decided to outline the Duquesne Light Company's approach to the development of these two markets, believing that, since it has produced reasonably satisfactory results for us, it might be of some interest to this gathering.

Type of Territory and Company Statistics

The Duquesne Light Company serves a highly industrialized area—its principal industries being iron and steel, coal, coke, aluminum, electrical equipment, food products, glass, etc. The population served is approximately 1,400,000 of which the City of Pittsburgh contains about one-half of this number. The area served is slightly over 800 square miles. The type of territory is principally urban and suburban with little or no rural area.

It is important to emphasize the competitive influences in our territory. Low priced, high btu content, natural gas offers severe competition to electricity for cooking and water heating and industrial heating applications. Cheap bituminous coal is a factor in the operation of isolated power plants.

As of the end of 1939 we had 346,720 customers classified as follows:

Residential	310,044
Small light and power	33,513
Large light and power	3,046
Miscellaneous customers	117

During the year 1939 our total operating revenue was slightly over $32,000,000. Out of each dollar of operating revenue 37 cents was received from the Residential customers, 14½ cents from the Small Light and Power customers, 39 cents from the Large Light and Power customers and 9½ cents from the Street Lighting and Other Miscellaneous customers.

Throughout this paper I will refer several times to our Small Light and Power classification and our Large Light and Power classification of customers and a definition of these terms is important in order to clarify our operations. Our Small Light and Power classification includes all customers, regardless of business classification, having connected loads below 20 kva. There are approximately 33,500 customers in this group. Our Large Light and Power classification includes all customers, regardless of business classification, having connected loads of 20 kva and above. There are approximately 3050 customers in this group.

MR. OUSLER

Principles of Approach

To effectively and economically develop any market certain principles must be followed which are just as pertinent to the utility business as to any other business. The market must be analyzed to determine its possibility of development; it must be stimulated by publicity, education, etc.; the consumer must be contacted by salesmen in the field; and last, but not least, there should be cooperation with all other branches of the electrical industry, including manufacturers, distributors, dealers, contractors and architects so that the maximum amount of promotion and direct selling contracts will result.

Organization

General

Our Sales and Service organization has been created on the basis of these principles. The entire operation is under the direction of a Vice-President in Charge of Sales with three men reporting to him; a General Sales Manager in Charge of all Gas sales; a General Sales Manager in Charge of all Electrical sales and a General Manager in Charge of Merchandising. The Duquesne Light Company, the Equitable Gas Company and the Equitable Sales Company are affiliated companies, each controlled by the Philadelphia Company, neither the Duquesne Light Company nor the Equitable Gas Company merchandise. The Equitable Sales Company, the merchandising outlet, operates as a dealer confining its operations almost entirely to the sale of residential gas and electrical appliances. The Equitable Gas Company serves about one-half of the area covered by the Duquesne Light Company; two non-affiliated gas companies serving the other half of the Duquesne Light Company territory.

Under the General Sales Manager of the Duquesne Light Company there are six departments—Rate Department, Retail Service Department, Sales Promotion Department, Residential Sales Department, Small Light and Power Sales Department and Large Light and Power Sales Department. Each department is in charge of a manager reporting to the General Sales Manager. Since this paper is to be confined to Commercial and Industrial Sales, I will comment only on the activities of three of these departments; namely, Sales Promotion, Small Light and Power and Large Light and Power.

Sales Promotion Department

The function of the Sales Promotion Department is to analyze our markets, prepare plans for the development of these markets, including cooperative sup-

port from other branches of the Industry, stimulate the use of electric service through various and diversified methods in accordance with these plans and analyze the results obtained as a guide to future operations. No direct sales contacts are made by this department. The majority of the work of this department is pertinent to the residential market. However, three of its personnel are assigned exclusively to promotional activities in the Commercial, Industrial and School fields.

The personnel of this department have been chosen for their ability to analyze markets and prepare and execute promotional plans. These men have had former sales experience either in the utility or some allied business. Obviously, they must be men of vision, but at the same time practical. They must be capable of convincing other branches of the electrical industry that cooperative plans, which they have prepared, are for the mutual benefit of all so that combined industry activities will result.

Small Light and Power Sales Department

The Small Light and Power Sales Department consists of a personnel of 14 including the manager. This is strictly a selling unit; has the responsibility of selling to customers in our Small Light and Power classification. About 70 percent of the customers in this group have loads of less than 3 kva, and 30 percent, or about 10,000 in number, have loads between 3 kva and 20 kva. For the past few years, the 12 field salesmen have been confining their efforts to contacting these 10,000 customers as this group seems to offer the best immediate possibilities of development. We have not determined as yet the most economical method of contacting the larger number of very small customers in this group. This problem is being studied at the present time.

The territory has been divided into 12 areas and one man contacts all the customers in the particular area assigned to him. These salesmen are of the all service type, promoting the use of all equipment which will increase the sale of kilowatthours. We do not use any specialists. The employees of this department are chosen for their potential sales ability and, generally speaking, need not be technical experts. During their training period they are closely supervised by the head of the department, sent to lighting schools of the General Electric Company and Westinghouse Electric and Manufacturing Company, and sent to plants of equipment manufacturers so that they will have complete information on the electrical appliances which they are trying to promote.

All of the salesmen in this group are paid a straight salary and are not compensated by load bonuses or merchandising commissions. They are graded by the amount of load which each is responsible for adding to our lines and a very careful check is made by the manager of the results which a man obtains. It does not take very long to know whether or not a man is going to fit into the picture—generally speaking six months, at the most certainly not over a year.

The salesmen in this department perform no service work. The Retail Service Department has the duty of signing and cancelling contracts, handling bill complaints, expediting service connections and the many other services which are pertinent to a large utility operation. Thus the personnel of the Small Light and Power Sales group are free to devote their entire time to selling.

Large Light and Power Sales Department

Our Large Light and Power Sales Department has the responsibility of selling to customers in our Large Light and Power classification. I think it would be interesting to state here that, of the 3050 customers in this group, 94 per cent have demands less than 300 kva and 6 per cent, or about 180, have demands of 300 kva and above. Included in this department are 19 salesmen and four supervisors. In addition to the salesmen there is a group of technically trained men who perform service work for the salesmen, such as economic studies, lighting layouts, plant studies, etc. They aid the salesmen by the preparation of reports which he uses in conducting his negotiations. These technical men do no selling.

All of the salesmen in this department are of the all service type as we use no specialists. They are paid straight salaries, are men with technical training and good sales ability. I emphasize again the necessity of salesmen in these jobs. It is true that the salesmen in this department must be men with technical education but they must also have sales ability. These men have been carefully chosen and trained. Good salesmen are not developed over night. The majority of these men, while young in years, have been in our employ for some time and with constant supervision by their superiors, training given through lighting, air conditioning, cooking, heating and similar schools, we have brought them to a point where they are proficient as all-service salesmen.

Each of the salesmen is assigned to a definite number of customers in a particular territory. The number of accounts handled per man varies. The men contacting the larger accounts have about 100 per man. The men handling the smaller customers have about 170 per man. Four of these salesmen, in addition to handling the sale of electric service, also sell steam to 300 accounts in the downtown triangle of Pittsburgh.

In addition to selling activities, the salesmen in this Department are responsible for service to customers such as signing and cancelling of contracts, expediting service connections, handling complaints, giving prompt attention to customer requests, etc. They have combined Sales and Service duties.

Organization Summary

With this type of organization, consisting of a Sales Promotion Department and two Selling Departments, we are developing additional uses of electric service among our Commercial, Industrial and School customers.

Commercial Market Development

Similarly to other territories, our Commercial (and here I use the term Commercial as a business classification and not a size classification) customers consist mainly of stores, restaurants, theatres, service stations, etc. It is our opinion that the best method of publicizing the benefits of electric service to our Commercial customers is by direct mail. Consequently we send out once a month a four-page, 8½ x 11-inch publication to a selected list of 15,000 Commercial customers, emphasizing the benefits which can be derived from adequate lighting, air conditioning, commercial cooking, etc. This publication contains illustrations and examples of local installations which have recently been made. It is sales slanted and contains customer benefit stories to stimulate the market.

In addition to this publication cooperative activities are conducted with manufacturers and distributors at certain times during the year. For example, in the fall we feature lighting; in the spring and early summer, air conditioning; and commercial electric cooking during the late winter months. An explanation of one of these cooperative activities may be of some interest. Let

us take, for example, the one on Store Lighting.

In a campaign on Store Lighting, meetings are first held with manufacturers and distributors at which time the Store Lighting activity is outlined. One of the most important features of the activity is publicizing the market. Therefore, during a specified period, educational direct mail pieces are sent out by the Duquesne Light Company and direct mail product advertising by individual manufacturers and distributors featuring the benefits of adequate lighting in stores. All of this direct mail literature is sent to a selected group of store customers according to a coordinated schedule which provides for a mailing every week or 10 days during the period of the activity. Each participating company is given a specific date for his mailing.

After the schedule of publicity has been arranged and is ready to put into execution, a second meeting is held with the manufacturers and distributors to explain to our salesmen the scope of the activity and at the same time to acquaint them with the manufacturers' products and prices so that they will be fully informed before approaching their customers. It is usual to announce at these meetings some type of contest, with prizes for the best results obtained, so that the particular activity can receive additional stimulation. Our salesmen take advantage of such a special activity and concentrate particularly on promoting store lighting during this period.

Similar cooperative activities with manufacturers and distributors are conducted at appropriate seasons in the year. Examples of some of these activities are: Commercial Cooking directed to restaurants, drug stores and other establishments which have use for counter cooking equipment; Air Conditioning for stores, restaurants, theatres, etc.; Outdoor Lighting directed toward gasoline service stations and similar establishments. Each of these cooperative activities acts as an additional stimulus in supplementing the regular routine promotional activities conducted independently by the Company throughout the year.

We have taken groups of merchants to lighting conferences at Nela Park in Cleveland. These trips were conducted at our expense and the results have well repaid us for our time and money expended.

These independent promotional activities of the Duquesne Light Company and the cooperative activities with manufacturers and distributors are followed through by the salesmen who are out in the field each day making contacts on the customers in their respective territories.

We believe that demonstrations are a distinct aid to sales. Therefore, these salesmen arrange for trial installations, where desirable, at no cost to the customer. Arrangements have been made with distributors who supply the equipment for these trial installations and the Duquesne Light Company arranges for a contractor to install them at our expense. In lighting activities these demonstrations, of course, involve only a few fixtures, but this is sufficient to give a visual impression of the approved appearances with adequate lighting.

As previously mentioned, the Duquesne Light Company does not merchandise. However, we have made arrangements for our Duquesne Light Company salesmen to take orders for equipment and turn these orders over to distributors and contractors for execution. We believe that this plan is quite essential, particularly in contacting the smaller stores, because it is extremely important to get the name on the dotted line before the customer has a chance to cool off and spend his money for other purposes. As I mentioned before, our salesmen do not receive any commissions even though they are directly responsible for an immediate sale of some piece of equipment by a jobber or contractor to a customer.

Our Commercial customers vary in size from very small ones up to some rather large installations—the largest a downtown Pittsburgh department store with a demand of approximately 2500 kva. For the larger Commercial customers, particularly those above 20 kva, technical assistance is given to the salesman by other technical men who are a part of the Large Light and Power Sales unit. This assistance consists of recommendations, plans and estimates for lighting, air conditioning, etc., economic studies in connection with isolated plants and any other technical data which the salesman needs for a particular negotiation. Thus the salesman is freed from such work and his time can be devoted to contacts with his customers.

School Lighting Activity

One of our most successful operations has been the promotion of adequate lighting in our schools. We have close to 1000 schools in our territory and we have made considerable progress in increasing the levels of lighting in our school classrooms. The approach to the School is somewhat different from the approach to the Commercial market. All benefits from adequate lighting are enjoyed by a third party, the children, and not particularly by the person who is responsible for the installation. Furthermore, this approach must have a humane appeal, not a commercial one. For these reasons our approach does not have the features of a campaign. It has been a steady educational activity over the last three or four years.

Once each month we are sending to about 1700 school officials, a single page direct mail publication, 8½ x 11 in. This publication features a local School Lighting installation which has been recently made according to the best recommended practices for the protection of young eyes. During the past few years we have conducted several trips to Nela Park at Cleveland. Up to the present time representatives from practically every School District have been given the opportunity to attend a School Lighting conference at Nela Park. Five of these trips have been made at a cost to the Duquesne Light Company of about $1,000 a trip. About 70 school officials were taken on each trip. This has been one of the best investments that our company has made from a promotional point of view. It has been possible through this means to give the story of Better Light for Better Sight to these school authorities in a most excellent and demonstrable way, which is only possible at an institution like Nela Park.

Our salesmen are constantly making contacts with these school officials, demonstrating equipment in the classrooms, providing these school authorities with educational pieces to show the value of adequate lighting. The approach to a particular school is generally by trial installation. One classroom is provided with adequate lighting and, if accepted, is then considered a standard for proper lighting levels. Other classrooms are brought up to this standard as available money will permit. In other words, to bring an entire school up to adequate lighting levels is, generally speaking, a piece-meal job. It works, however, and we are pleased with the reception that the school authorities have given to adequate lighting in our Western Pennsylvania schools.

Industrial Market Development

The Industrial market in our territory is a very large and important one. It is made up of different types of fac-

tories, laundries, dairies, brick plants, ice plants, small and large coal mines, glass plants, steel fabricating plants, steel mills and many industries associated with the manufacture of steel. There are some small industrial plants in our Small Light and Power classification below 20 kva of connected load but the majority of the industrial plants fall into the Large Light and Power classification.

The Industrial market differs somewhat from the Commercial market in that there are additional factors present in the former which do not exist in the latter, at least not in the same degree. For example, in our Industrial market there are many possibilities of isolated plant operation, making it necessary for the salesman to be extremely alert to this competitive factor, not only in connection with negotiating business with new customers, but also retaining business with our present customers. The development of our Industrial market can, therefore, be divided into four parts:

1. The sale of increased service to our present customers.
2. The sale of service to new plants locating in our territory.
3. The sale of utility service to the customer now operating an isolated plant.
4. The retention of present business against the inroads of isolated plant competition.

As is true in developing our Commercial market we believe that it is necessary to also publicize the Industrial market. Consequently we prepare and send out each month to 3500 industrial executives a direct mail publication called "Industrial Electric Topics" which is a four-page leaflet 8½ x 11 in. in size. This publication is used for general coverage in promoting plant lighting, large and small electric heating, ventilation, power applications, infra-red drying, etc. In addition, other publications having general and specific coverage are also sent out monthly to this market. Similarly to the publication "Commercial Electric Topics," this "Industrial Electric Topics" and other publications contain illustrations of local applications, the benefits derived from these applications and an attempt is made to keep the publications as sales slanted as possible.

At specific times during the year cooperative activities are carried on with manufacturers and distributors on specific items such as factory lighting, ventilation, small electric heating, etc. I will not go into the details of these cooperative activities because they are carried on in a manner similar to those that are conducted in approaching the Commercial market. I think it is sufficient to say that we believe that these cooperative activities are desirable and the manufacturers and distributors are extremely willing to cooperate in them.

Our trips to Nela Park for our Commercial customers and our school officials had such good results that we decided to conduct similar trips for Industrial plant men. To date two of these trips have been taken and, here again, we feel that they have produced good results. These trips, as in other instances, are conducted at our expense.

It is our opinion that the major factor in developing our Industrial market is the salesman. It is his duty to secure new customers, retain present business and increase the use of our service by present customers. He makes periodic calls on his customers in order to develop sales and create good public relations; he keeps his customers informed by means of calls or printed articles on new developments in the electrical utilization field and attempts to make a sale where these new developments have application. He keeps informed regarding changes in customers' operations in order to be in a position to sell additional service. He advises customers on their operations so that the customer can purchase his service, in accordance with the rate, at the least possible cost per kilowatthour. He constantly analyzes conditions in these industrial establishments in order to effectively plan his sale over a period of months and years. He keeps himself up-to-date on new uses of electric service by attending meetings of technical organizations, by reading trade journals, by demonstrations and by attending schools given by manufacturers.

In contacting Industrial customers, the salesman has need for a great deal of assistance in the way of technical help. This is furnished by the other technical men in the Large Light and Power group in a manner similar to the technical assistance given to a salesman contacting the large Commercial customer. These economic studies, lighting layouts, plant studies, etc., involve considerable time, and since the salesman is relieved of this burden he is free to devote his entire time to his Sales and Service activities. As I mentioned previously, all of these technical studies are given to the salesman to be used in his negotiations. The men conducting the studies do no selling.

In the Industrial market one salesman, generally speaking, is the only point of contact with a customer—numerous specialists are not calling on this same customer. The salesman, within a reasonable time, becomes acquainted with the "key" men of the company which he is contacting. We can rely on these salesmen to do an effective and proficient job in handling their accounts, not only from the viewpoint of acquisition of load, but at the same time causing the best relations with these customers. I have personally visited many of our customers with these salesmen and I find that each is well acquainted with the "key" men of the company which he contacts, almost to the degree that he is able to get audiences with the presidents and vice-presidents of the larger firms even more quickly than are the personnel in these establishments.

Simplified Rate Structure

While the subject of rates is not particularly pertinent to this sales paper, I believe that I would be eliminating a rather important factor if I, at least, did not mention one point in connection with our rate structure. It is the fact that we have no optional rates. I believe that this is a distinct aid to selling and the development of good relations with our customers.

After many years, we have finally developed a rate structure with only one rate available for each class of service, determined by size. We have General Service Rate (small) applicable to all customers with loads of 1 kva or less; a second General Service Rate (medium) applicable to all customers in excess of 1 kva but not more than 5 kva of connected load; and a third General Service Rate (large) applicable to all customers with connected loads over 5 kva. Once the size of a customer is determined there is only one rate available to him. As I said before, we have no optional rates. Our customers now realize that each is paying an identical rate per kilowatthour for similar load and load factor conditions.

Results

To the executive of a large utility company the most important point in his mind is results. While he is always interested in organization and approach, his principal thought is centered on accomplishments and costs.

Summary

I have made an attempt in this paper to cover very broadly our approach to the development of the Commercial and Industrial markets so that you might

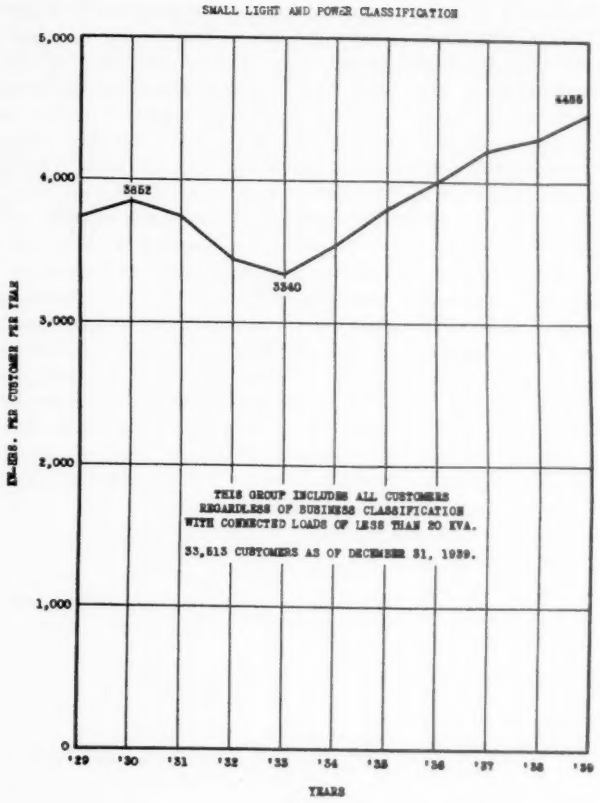

Chart 1

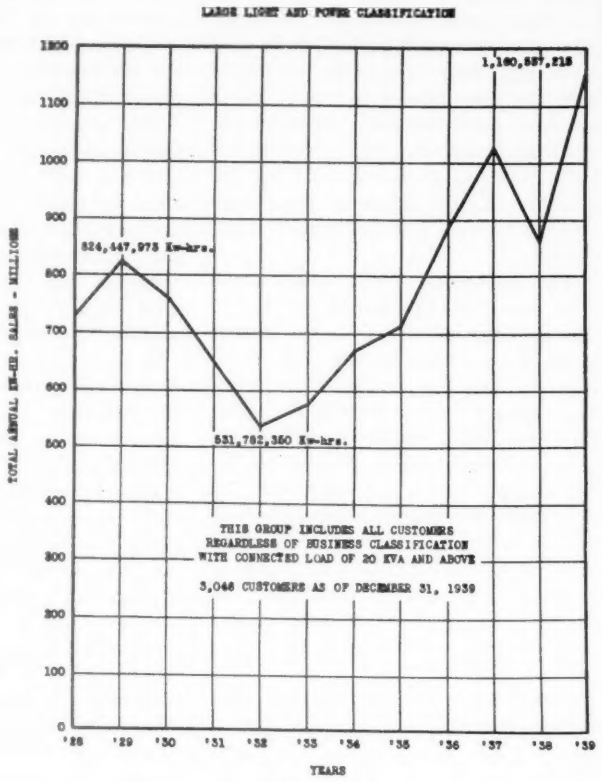

Chart 2

Chart 1 shows the annual use per customer in the Small Light and Power Classification for the last eleven years, 1929 to 1939, inclusive. These are the customers, approximately 33,500 in number at the end of 1939, regardless of business classification, under 20 kva of connected load. At the end of 1939 this annual use per customer was approximately 4500 kilowatthours. You can see from this chart that we are enjoying an increase of about 200 kilowatthours per customer per year.

Since the majority of the customers in this group are very small in size, it may be interesting to compare these increases in use per customer per year with our Residential group. During the last five years our Residential annual use per customer rose from 754 to 968 (with practically no electric ranges or water heaters on our lines), a gain of 28½%. The annual use per customer in the Small Light and Power group, during the same five-year period, rose from 3550 to 4500, a gain of about 27%. The percentage gains in these two groups are fairly comparable.

Chart 2 shows the total annual sales in kilowatthours for the last twelve years, 1928 to 1939 inclusive, to the customers in the Large Light and Power Group—those customers, regardless of business classification, having connected loads of 20 kva and above. Due to the extreme variation in size of individual customers in this group, it is not very practical to show results in use per customer per year. This exhibit therefore has been prepared on the basis of total annual sales per year to the entire group. This exhibit shows that in 1939 our sales were 40% greater than in 1929, the peak reached before the depression, and over double the sales in 1932, the worst year of the depression.

This increase in sales is made up of increased use by present customers, the sale of kilowatt-hours to customers formerly operating private plants, the sale of service to some new customers who have located in our territory, the largest of which was a new sheet mill which started operations in 1938. The curve also reflects variations in business cycles, particularly noticeable by the drop in sales from 1929 to 1932.

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have a picture of the general scope of our activities. I have included as much detail as is possible in the time allotted. I think I can best summarize the paper by emphasizing what I believe are some of the essential features of our approach:

1. Sales promotion activities coordinated with manufacturers and distributors are essential to the development of these markets.

2. We find that all service salesmen are most effective in our sales contacts. We do not believe in specialists.

3. We emphasize the importance of good salesmen, technically trained at least for the larger customers, but primarily salesmen and not just technicians.

4. We divorce all technical studies, layouts and sales promotion work from the selling units so that the salesman will be free to spend practically his entire time in the field contacting customers—sales are not made in the office. The old theory that it is necessary to make a number of contacts before a sale is consummated is just as true in the utility business as in any other business.

5. Close supervision of salesmen is desirable. We have set up in each department, under the manager, a sufficient number of supervisors so that each supervisor will not have too many men under his direction. These groups vary from a minimum of four to a maximum of twelve.

6. Particularly for the small commercial and industrial customers, we believe that demonstrations are a very effective aid in selling and we make many of them.

7. The salesmen contacting, particularly, the small commercial customers have authority to take orders for lighting equipment and appliances and turn these orders over to contractors and distributors for execution. It is our opinion that this is extremely essential in order that a sale may be consummated immediately before a customer has the opportunity to change his mind.

This is just one method of approach. We do not claim it as the best, but it is producing results for us.

I have only one further comment—Commercial and Industrial markets are fertile fields but they need cultivation. Promotion, independent and cooperative, emphasizing the benefits of doing things electrically, is essential. Customers must be contacted by alert, enthusiastic and competent salesmen selling these benefits—we can not sit back and wait for orders or expect someone else to do the job for us. To develop these markets to the maximum degree is a selling job, and should be the responsibility of an alert and aggressive sales department if results are to be obtained.

Magnetic Storms

By A. G. McNish

Department of Terrestrial Magnetism, Carnegie Institution of Washington

Address before the Dinner Meeting of E.E.I. Engineering Committees, Chicago, Ill., May 7, 1940

IT SEEMS a bit strange to me, and perhaps it does to you also, that a research worker in terrestrial magnetism should be speaking to an audience of practical electrical engineers. However, there are some things we have learned from our studies of terrestrial magnetism which may prove helpful—at least they should prove consoling—to members of the engineering profession. Mr. Davidson and Mr. Germaine will describe the effects on power and communication lines produced by the great magnetic storm which occurred on Easter Sunday, March 24, 1940. They will explain from the engineer's point of view how these effects resulted from voltages caused in the lines by the magnetic storm. I shall attempt to explain how the voltages were caused.

In doing this I shall describe the greatest super-power system in the world—a system so vast that its effects extend not only to every state in our country but to every continent and sea in the world. Like the hydro and steam plants of our man-made systems the energy of this super-power system is derived from the sun. Its distribution lines are the earth and the atmosphere, and when these distribution lines are tapped, as is done by grounded communications and power circuits, large currents are encountered.

One usually thinks of the energy-changes during a magnetic storm as small, the field-changes as inconsequential. This view is correct if one is thinking only of the space within a laboratory-room or within a transformer, but it is misleading because the field of a magnetic storm extends through a greater volume of space than the earth occupies and the total energy of a magnetic storm integrated throughout that space reaches an appalling magnitude.

During the great magnetic storm of April, 1938, energy was expended at the rate of two billion kilowatts for a two-hour interval. Couched in more comprehensible terms this is 100 times the capacity of all the hydro-electric developments in this country and four times the estimated potential developments of the entire world. Thus all the power plants of the world, if hooked together, could not supply enough power to produce the effects of a great magnetic storm. The magnetic storm of last March which produced so much disturbance on power and communication lines seems to have been greater than the storm of April, 1938—possibly it is the greatest magnetic storm which has ever been recorded.

To the neophyte in terrestrial magnetism the only regular characteristics of magnetic storms is their characteristic irregularity. On ordinary days gradual changes occur in the earth's magnetism which are repeated from day to day with fair reliability. During magnetic storms these gradual variations are overwhelmed by large erratic fluctuations, so violent in character that ordinary photographic equipment suitable for recording the daily variations is sometimes inadequate to meet the requirements (see Fig. 1). However, the increased interest in these phenomena which has arisen during re-

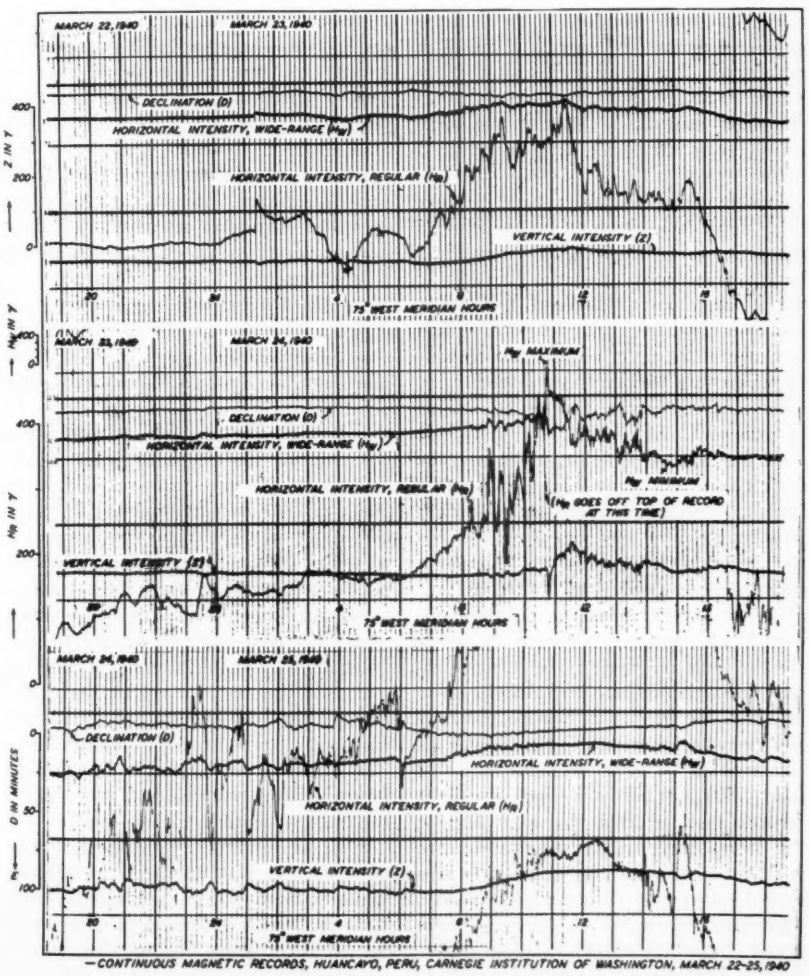


Fig. 1

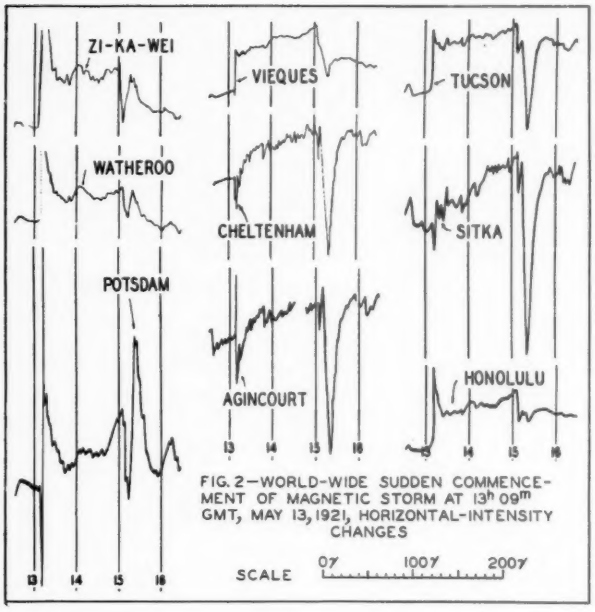


FIG. 2—WORLD-WIDE SUDDEN COMMENCEMENT OF MAGNETIC STORM AT $13^h\ 09^m$ GMT, MAY 13, 1921, HORIZONTAL-INTENSITY CHANGES

Fig. 2

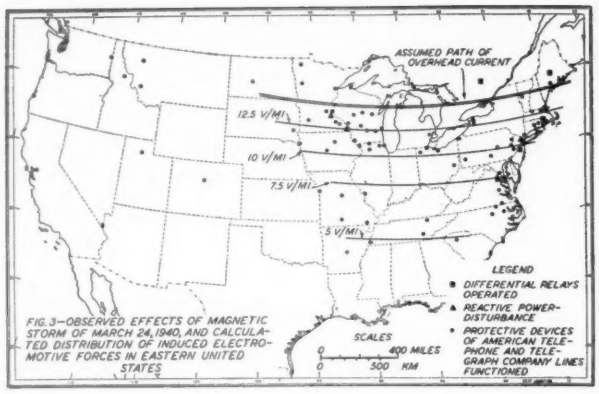


FIG. 3—OBSERVED EFFECTS OF MAGNETIC STORM OF MARCH 24, 1940, AND CALCULATED DISTRIBUTION OF INDUCED ELECTROMOTIVE FORCES IN EASTERN UNITED STATES

Fig. 3

cent years, owing in part to their effects on our electrical systems, has caused a number of observatories to install wide-range recorders capable of obtaining complete records of greater magnetic storms than have ever been experienced before.

Systematic features appear among these apparently random variations of a magnetic storm when they are examined by an experienced student. The erratic fluctuations may be likened to sudden gusts of wind in a thunderstorm which are superposed upon a general and constant current of air the direction of which is predetermined by considerations of time and geography.

A number of generalizations may be drawn from our knowledge of magnetic storms. In the first place, each storm is world-wide. One sometimes reads in the newspaper such headings as "Magnetic storm sweeping northern United States" as if that region were the only one affected. This notion is far from the truth, for the same magnetic storm which produces disturbance in North America also produces disturbance in Europe and Asia and even in Antarctica. This is well illustrated by the great magnetic storm of May, 1921, for which we have excellent records showing that the beginning of the storm was strictly simultaneous to within a few seconds at such widely separated places as Tucson (Arizona), Agincourt (Canada), Vieques (Puerto Rico), Sitka (Alaska), Potsdam (Germany), Watheroo (Western Australia), and Zi-ka-wei (China) (see Fig. 2).

Of course, there are regions of the earth where the effects of magnetic storms are more pronounced than at others. In equatorial regions effects of magnetic storms are least violent while at a distance from 20 deg. to 30 deg. from the geomagnetic poles they attain their maximum intensity. This polar region of maximum activity is called the auroral zone; it is the region of the earth where auroras are most frequently seen. Near the auroral zone the currents induced in the earth which affect transmission and communication lines also are more intense. Some evidence on this point is supplied by the fact that most of the disturbances of communication lines occurred in the northern part of this country during the storm of March 24, 1940, while power systems in the southern states did not report any interference. Similar geographic distributions apply to the effects of magnetic storms on radio transmission—channels of communication in high latitudes being principally affected. During a great number of magnetic storms communication with Europe has been maintained by routing European traffic through South American stations and thus avoiding the high-latitude direct channels to Europe which are most susceptible to disturbance.

One outstanding feature of great magnetic storms is that this auroral zone where disturbance is most intense shifts to lower latitudes. Auroras are seen very far from the poles during great storms, even within the Torrid Zone. We have reports of visible auroral phenomena during great magnetic storms even in such tropical stations as Bombay (India) and Apia (Samoa). Correspondingly intense disturbance of the earth's magnetism with attendant activity of earth-currents likewise occurs in lower latitudes during great magnetic storms.

Mathematical analysis has shown that field-changes during magnetic storms are due principally to causes above the earth's surface, presumably electric currents, and that these external effects are accompanied by effects due to the induction of currents within the earth by the primary external fields. It is an unfortunate limitation of mathematical analysis that it cannot describe uniquely both the location and configurations of these external currents, although with the assistance of mathematical analysis and some other considerations one may deduce probable locations and configurations. The field-changes may be divided into two classes—those which are symmetric about the earth's magnetic axis and those which are non-symmetric. The first class may be thought of as due mainly to a large ring-current about the earth, like the rings of Saturn, or to a current flowing in the outer atmosphere with intensity varying as the cosine of the geomagnetic latitude from zero at the geomagnetic poles to a maximum at the equator. The inferences we may draw from magnetic observations are entirely ambiguous in this regard for they permit either possibility. If the ring-current is the correct concepton its radius may be several times that of the earth.

During the first phase of a magnetic storm the current in this ring flows from west to east and during the main or second phase it flows from east to west; the magnitude of the current reaches several million amperes at its maximum during great magnetic storms. Although the greater part of the energy of magnetic storms is involved in this hypothetical ring-current, the magnetic changes are not rapid enough to induce the very high potentials within the earth which play havoc with electric systems.

The second class of field-changes, which are non-symmetric about the earth's geomagnetic axis, are associated with electric currents flowing with maximum intensity along the auroral zone. There is every assurance that these currents are confined to our atmosphere, probably at a height of about 100 kilometers or so, where radio observations and auroral phenomena attest that the atmosphere is highly ionized. Field-changes arising from these currents are responsible for the effects on communication and power lines.

Observation of the field-changes at a number of stations during various magnetic storms has permitted mapping of typical current-circulations. In general, these consist of intense currents flowing in an east-west direction along the auroral zone with diffuse return-circulations —also confined to the atmosphere— across the polar cap and in low latitudes. Westward currents predominate on the morning side of the earth and eastward currents on the afternoon side, the westward currents being in general more intense. Such currents may continue for an hour or several hours but rapid changes in their intensity take place. Obviously, with such a distribution of currents, although a magnetic storm may be occurring all over the earth, certain places will be subject to more intense disturbance depending upon the location of the place and the time of day at which the magnetic storm began. The strength of these auroral-zone currents may exceed 1,000,000 amperes and changes exceeding 100,000 amperes in one minute have been observed. Although the path of the current along the auroral zone may be 100 miles or so in width, to a first approximation it may be regarded as confined to a vast trolley-wire stretching for hundreds of miles in an east-west direction at a height of about 100 miles above the earth.

Calculation of the potentials induced in power lines from such a changing system of electric currents is readily accomplished. On first thought one might be inclined to attempt this by estimating the flux-change throughout a loop bounded by the transmission line and a somewhat uncertainly defined return-circuit in the earth between its grounded ends. Values obtained in this way are much smaller than those which have been observed. Furthermore, this calculation would imply that the current within the earth flows in a direction opposite to that in the power line. The correct point of view regards the power line and the earth beneath it as parallel conductors—the power line serving as a by-pass for the currents flowing in the earth.

The electromotive forces E in the power line and in the earth are calculated from the magnetic vector-potential A by the formula

$$E = dA/dt = d[\int (I/r)ds]/dt$$

in which I is the current flowing in the atmosphere, r its distance from the point for which the vector-potential is being calculated, and s a vectorial element of length along the path of the current. Sufficiently accurate results for our purpose are obtained by assuming that the current is confined to a path some 2500 km long, of infinitesimal cross-section, at a height of 200 km above the earth's surface. Curvature of the earth and effects of the diffuse return-circulation from the ends of the path of the main current will be neglected. The path of the current may be assumed to run in a general east-west direction centered over the Great Lakes. Directly under the current the induced electromotive forces will have their maximum value which falls off but slowly for a distance of about 125 miles. At about 400 miles from the current-path the electromotive forces are about one-half their maximum value and remain of inconsequential magnitude throughout the South (see Fig. 3). Changes in the intensity of the auroral-zone currents of from 10,000 to 15,000 amperes per second would be sufficient to produce electromotive forces of the magnitude required for effects on power-lines (about 10 volts per mile). Although these fluctuations are somewhat larger than what would ordinarily be expected on the basis of past measurements they do not greatly exceed what has been frequently observed. On the other hand the storm of March 24, 1940, produced greater disturbance on power and communication lines than has ever been reliably reported before. In case a power line spans a portion of the earth's crust which has a higher specific resistance than adjacent regions the induced electromotive forces are likely to be increased by "line-drop" of the currents flowing in extensive areas of the earth.

The cause of the primary electric currents in the outer atmosphere or about the earth remains a matter of speculation. We know definitely that solar activity is directly responsible for magnetic storms —magnetic storms vary in frequency with the sunspot-cycle and exhibit a

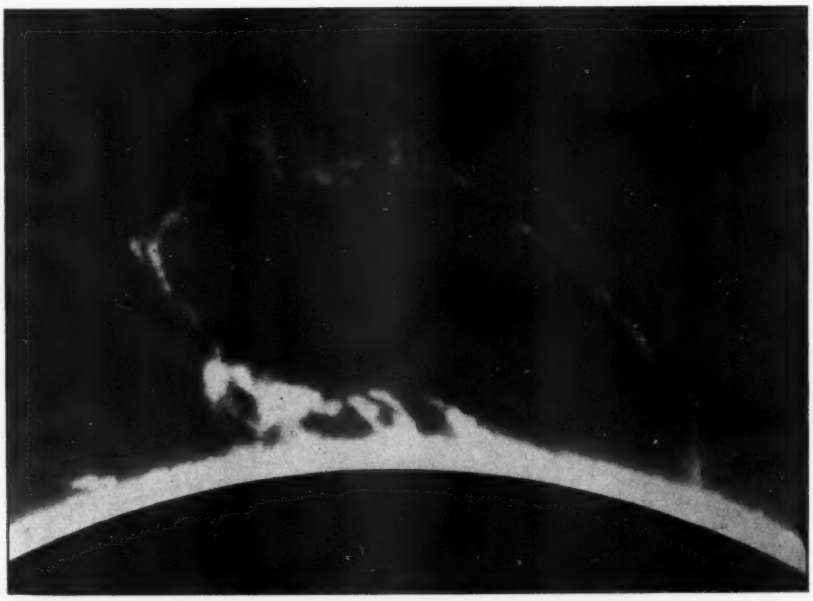


Fig. 4—Eruptive Prominence on Limb of Sun—Clouds of Ionized, Hot Gases Being Ejected from Chromosphere

quasi-periodic effect which is associated with the sun's rotation. How is this solar influence transmitted to the earth? The best we can do is to consider the most plausible hypothesis.

It is believed that the sun ejects clouds of electrified corpuscles. Some evidence in support of this is supplied by moving-picture records of masses of hot, ionized gas being tossed to great heights in the solar chromosphere parts of which appear to escape into space (see Fig. 4). Occasionally these clouds of particles strike the earth and as they do they are focused by the magnetic field very much as electrons are focused by the magnetic field in the newly developed electron-microscope. Mathematical treatment shows that electrified particles of certain energies and masses will reach the atmosphere with greatest density in belts near the magnetic poles (the auroral zones) and that others will occupy semi-stable orbits in the plane of the magnetic equator. Many years ago Birkeland demonstrated the qualitative correctness of this theory by directing a stream of electrons toward a small magnetized sphere and showing that both the equatorial ring and auroral zones could be reproduced experimentally (see Fig. 5).

The electrified corpuscles which reach the outer atmosphere ionize the atmospheric gases and produce luminescence which is revealed as auroral light. The mechanism whereby the electric currents are produced is still not satisfactorily explained. It is likely that the "ring-current" is a simple manifestation of the motion of the electrified particles themselves and that the auroral-zone currents result from convective motion of the atmosphere in the earth's magnetic field by which means the currents are induced in accordance with the principle of a dynamo.

Regardless of the causes of magnetic storms there is nothing scientists or engineers can do to control them. Their effects on power and communication lines can be reduced to inconsequential importance by suitable installations but the cost of these installations involves economic considerations. Here the scientist is in a position to render definite service to the engineer, since, on the basis of lengthy records, he may hazard a guess at the probable frequency of great magnetic storms in the future. Definite prediction of individual great magnetic storms is not possible now and hope of accomplishing this in the future is extremely feeble. Perhaps a great magnetic storm may occur within a month; perhaps no more

(*Continued on page* 370)

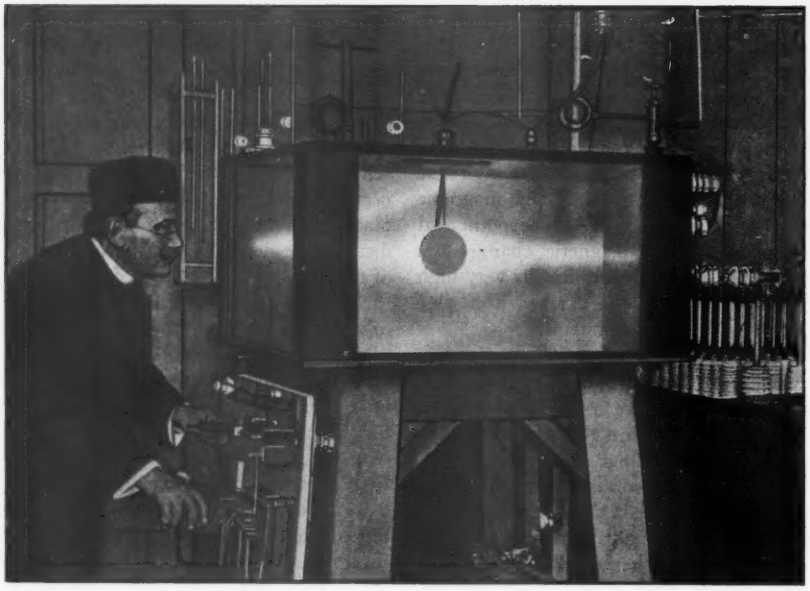


Fig. 5—Birkeland and His Experiment to Demonstrate Corpuscular Origin of Magnetic Storms

TABLE 1—GREAT MAGNETIC STORMS

Date	Ranges*			Station	Remarks
	Declination	Horizontal intensity	Vertical intensity		
	′	γ	γ		
1859, Aug. 28-Sept. 7	140	700(?)	400(?)	Greenwich, England	
1872, Feb. 4	....	> 960	....	Bombay, India	Aurora seen at Bombay
1882, Nov. 17-21	115	>1090	>1060	Greenwich, England	Largest sunspot-group of that cycle on Sun
1903, Oct. 31-Nov. 1	186	> 950	> 950	Potsdam, Germany	
1909, Sept. 25	210	>1500	>1100	Potsdam, Germany	Lasted only about 10 hours
	68	800	235	San Juan, Puerto Rico	
1921, May 13-16	199	1060	1100	Potsdam, Germany	Aurora seen at Samoa
	>120	> 800	>1000	Cheltenham, Maryland	
	96	>1100	453	Watheroo, Western Australia	
1938, Apr. 16	328	1900	600	Potsdam, Germany	Lasted only about 10 hours
	25	1320	118	Huancayo, Peru	
	291	1120	1020	Cheltenham, Maryland	
1940, Mar. 24-25	135	2300	900	Potsdam, Germany	Disturbance of power-circuits in North America
	137	850	1100	Cheltenham, Maryland	
	21	1390	122	Huancayo, Peru	

*Expressed in minutes of arc for declination and in γ (1γ = 0.00001 gauss) for horizontal and vertical components.

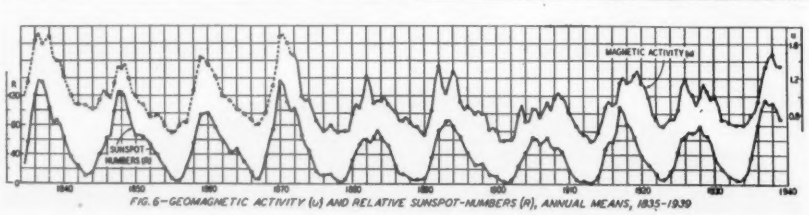


FIG. 6—GEOMAGNETIC ACTIVITY (u) AND RELATIVE SUNSPOT-NUMBERS (R), ANNUAL MEANS, 1835-1939

Fig. 6—Geomagnetic Activity (U) and Relative Sunspot—Numbers (R), Annual Means, 1835-1939

The Magnetic Storm of March 24, 1940—Effects in the Power System

By W. F. Davidson

Director of Research, Consolidated Edison Company of New York, Inc.

Address before the Dinner Meeting of E.E.I. Engineering Committees, Chicago, Ill., May 7, 1940

THESE notes are a summary of data on the influence on power systems of the magnetic storm of March 24, 1940. The basic information was obtained from 22 power companies scattered about the United States and in Canada. Disturbances on power systems were reported by companies in New England, New York, eastern Pennsylvania and southern and eastern parts of Minnesota and in Ontario and Quebec. Reports of "No Trouble" were received from systems in North Carolina, Georgia, Alabama, Illinois, Nebraska, Kansas, northern Minnesota, Utah, Idaho, Washington and California.

Of the 10 systems on which disturbances were noted, the effects, listed in the inverse order of the number of cases reported, were:

1—Voltage dips ranging up to 10 per cent but generally of short duration (7 cases).
2—Tripping transformer banks by differential relay operation (5 cases involving 15 transformer banks).
3—Large increases or swings in reactive kva (4 cases).

In addition, we have three separate observations:

1—Direct current was measured in a neutral grounding connection (1 case).
2—Distortion of the current wave in a neutral grounding connection was recorded by oscillograph (1 case).
3—A few blown transformer fuses on a 2400/4150 volt radial distribution system (1 case).

No serious operating difficulties or interference with service were reported, possibly because it was Easter Sunday and loads were unusually light.

Taking some of the specific cases and first examining those involving transformer tripping:

A—On the 220 kv system of the Philadelphia Electric Company—Public Service Corporation of New Jersey—Pennsylvania Power and Light Company in eastern Pennsylvania and New Jersey, voltage surges ± about 1½ per cent and reactive power surges of 20 per cent were observed on the Conowingo-Plymouth Meeting circuits. At about the same time, that is, 11:48 a. m. E.S.T., two 75,000-kva transformer banks at Siegfried were tripped out by differential relay operation. This system operates with neutrals grounded at each transformer bank. The 220 kv circuits from Siegfried run 48.7 miles in a southeasterly direction to Plymouth Meeting, 65.7 miles in a northeasterly direction to Wallenpaupack and 82.2 miles easterly to Roseland. The latter two circuits are connected together at a point central between the three terminals. The transformers are connected Y-Y, 220/66 kv with delta connected tertiary windings.

B—On the system of the Central Maine Power Company at Bucksport, there are two transformer banks supplied from the 110 kv lines. One of these banks is 15,000 kva with 6600 and 2300 volt low-voltage windings. The other transformer bank is 5000 kva with 33 kv low-voltage windings. The high-voltage windings are connected Y with neutrals grounded and the 110 kv system is grounded at 4 other points. At about 11:50 a. m. E.S.T., both transformer banks were tripped out by differential relay operation. The smaller bank was restored to service immediately but when the breakers were closed on the larger bank both were again tripped out by relay operation. A second effort to restore service was made at 12:40 p. m. and no further trouble was experienced. During the period from 10:50 a.m. to 2:00 p. m. numerous voltage dips were observed on the 2300 volt bus, some of these being as large as 8 per cent. The load was small, ranging from 800 to 1000 kw with no fluctuations of sufficient magnitude to explain the voltage dip.

C—In Providence, the Narragansett Electric Company has a 40,000 kva transformer bank connecting the 11 kv and 110 kv systems. This transformer bank was tripped out by operation of the differential relays. Following this, an ammeter was put in the transformer neutral and a direct current of 25 amperes was recorded. At the time of this observation, no operating difficulties were being experienced.

D—On the Ontario Hydro Electric Commission 220 kv system of the Niagara District, 4 transformer banks at Chats Falls transformer station tripped out at 11:48 a. m. E.S.T. In two cases, tripping was caused by operation of the transformer differential relays and in two cases by operation of the bus differential relays.

E—On the Ontario Hydro Electric Power Commission 132 kv Abatibi system, six transformer banks tripped out by differential relay operation at 11:48 a. m. E.S.T. Two of these transformer banks were located at Kirkland Lake transformer station, three at Copper Cliff transformer station and one at Timmins transformer station. This system is supplied by a main generating station at Abatibi Canyon from which a two-circuit line extend 150 miles southeast by south to Kirkland Lake transformer station and another two-circuit tower line extends directly south 100 miles to Timmins transformer station and thence an additional 143 miles south to Copper Cliff transformer station.

An analysis of these cases shows that in each of them single phase transformers were used in the transformer banks and that there were neutral grounds both at the transformer bank and other points on the transmission network.

Next considering cases involving reactive power surges:

F—The reactive power surges on the 220 kv Conowingo-Plymouth Meeting Circuits have already been mentioned—they amounted to about 20 per cent.

G—On the Newberryport-Haverhill 22 kv double circuit line of the Eastern Massachusetts Electric Company, the current was in the order of eight amperes, or about the charging current of the line, until late in the morning when the disturbances began. At that time swings to as high as 60 amperes or somewhat more than normal full load current, were observed. Individual swings had a duration of a minute or less but recurred at frequent intervals over a period of some 10 or 15 minutes. There was considerable accompanying voltage drop.

H—Our information concerning the system of the Northern States Power Company centering about Minneapolis relates principally to the 69 kv circuits. These are extensive and are laid out roughly northeast-southwest direction over a distance of something more than 250 miles. Transformer banks are generally Y-delta with grounded neutrals on the 69 kv side and a few auto-transformers to the 115 kv system—these having delta connected auxiliary windings. Single phase transformers are the rule. As is well known, the distribution system in the Minneapolis area is four-wire common neutral radial.

On the morning of March 24, there was 105,000 kw steam generating capacity in service in stations in the Minneapolis area and 10,000 kw of steam-generator capacity at Minnesota Valley, roughly 100 miles west. Two 10,000 kva synchronous condensers were operating in the Minneapolis area and one 5000 kva synchronous condenser at Mankato about 110 circuit miles to the southwest.

The first disturbance in the nature of a surge as indicated by shift of load on the synchronous condensers was observed at about 10:45 a. m. E.S.T. This was followed by numerous other surges at irregular intervals until 1:45 p. m. E.S.T. There was a slight recurrence of minor severity between 10:30 and 12:15 p. m. E.S.T. The most severe of the surges occurred at about 11:50 a. m. E.S.T. when the total build-up and decay period seemed to cover about four minutes. During that time the synchronous condensers which were operating on voltage regulators shifted load from maximum buck to maximum boost and return. There was an accompanying drop in voltage of about 10 per cent. Considerable surges in reactive

component on several of the circuits such as the Wissota-Oak Park 115 kv line where a change of 10,000 kvar was recorded. The graphic wattmeters showed no corresponding indication of the disturbances and there were no circuit breaker operations.

At Sparta, approximately 150 miles to the southeast of Minneapolis, the 69 kv line regulating transformer operated to the extreme position in each direction and a lightning arrester discharge was noted.

I—On the Consolidated Edison 60 cycle system in New York, a series of voltage disturbances took place beginning about 11:48 a. m. E.S.T. The first dip, which varied from 1½ per cent to 10 per cent in different parts of the system, was followed by a series of minor dips continuing at short intervals for a period of about one hour. The 25 cycle system voltage was not affected nor was there any appreciable change in system frequency or change in kw load in any part of either system. The voltage dips were of lower magnitude than those often caused by high voltage feeder faults and did not have any serious effect on operation of customers' equipment or on the operation of the system.

Kvar recording instruments are available at only a few locations on the system. The principal point is at the Hudson Avenue Generating Station where there is a station totalizing meter and in addition at eight substations in the Brooklyn area each having curve-drawing kvar meter. Voltage dips beginning at 11:48 were recorded by several voltage dip recorders, these generally showing a duration in the order of 24 seconds.

An extended study of recording voltmeter charts shows that the voltage drops were generally small in the a-c network areas and usually of the same order of magnitude as observed on the station bus from which they were served. Rather larger drops were observed on the four kv radial systems supplied from the substations, the values here ranging from 2 per cent in the Bronx district supplied from Hell Gate Station to 5.5 per cent for the radial system of Brooklyn to as much as 10 per cent for parts of the radial system in Westchester County. An analysis of the available data indicates that there was a large increase in the reactive load on the radial systems, this amounting to 33,000 kvar for the Brooklyn area, 20,000 kvar for the Westchester area and proportionately smaller amounts for the others. The contributions from the various stations totaled 45,500 kvar, of which nearly one-half or 21,000 kvar was contributed by the Hudson Avenue Station.

At the Hudson Avenue Station where data were available on voltage dip and increased reactive component demand, it was found that these were consistent when generator characteristics were taken into account. For the other stations, therefore, the values of increase in reactive demand were computed from the observed voltage dips.

J—In addition to the several cases cited above where voltage dips were observed, it may be noted that in the 13.2 kv system of the Public Service Electric and Gas Company of New Jersey, there were voltage drops from 3 to 4½ per cent.

K—On the 110 kv system of the Niagara Hudson Power Corporation, there were numerous operations of the automatic oscillograph installed at Lockport. The first of these operations occured at 10:44 a.m. E.S.T. and was followed by numerous others until the supply of film had been exhausted. This supply was replaced and five more operations were recorded, the last at 11:41 a. m. when the oscillograph was left out of service. Neutral current records obtained show in several cases a small peak at each cycle of the 60 cycle wave with a flat portion in between. This has the appearance of a characteristic current wave with a transformer operating with direct current superimposed on alternating current excitation but since the oscillograph was operated through a current transformer there was no direct observation of d.c.

L—The Boston Edison Company reported a considerable number of blown transformer fuses on its 2400/4150 volt radial distribution system. All were on transformers at the ends of feeders at points where the neutral was continued past open tie switches to feeders in adjacent areas.

For the purpose of explaining what happened in the power systems I shall refer chiefly to the New York system for which the most extensive analysis has been made. It was noted that:

1. There had been voltage dips of short duration and considerable magnitude.
2. There had been increases in kvar coincident with the voltage dips and proportionate to them.
3. There had been no appreciable change in the power components—i.e. in kw load.

These phenomena were, at least qualitatively, what would be expected if direct currents flowed in the windings of transformers so as to cause saturation and lead to increased a-c magnetizing currents.

The radial distribution system afforded all the necessary conditions. The 2400/4150 volt primary feeders are supplied from substations with delta-Y transformers, while the distribution transformers are single phase with interconnected neutrals and waterpipe grounds at services. Differences of earth potential could set up direct currents from service neutrals, through transformer primaries, and to earth again along the primary conductors and through station transformer windings. Test data available showed that for distribution transformers of this type each ampere of direct current in the primary would cause an increase in a-c magnetizing current equivalent to about 4 kvar. By applying these basic assumptions, and the assumption of an earth potential gradient of 10 volts per mile to the characteristics of a typical radial feeder, it was calculated that there would be an increase of 11.5 kvar for each 100 kva of distribution transformer capacity, or for the Brooklyn area a calculated increase of 26.4 mvar compared with an observed 25 mvar.

It is necessary, here, to point out certain important differences when three-phase transformers are involved. If these are of the three-leg or "core" type, direct current components flowing from line terminals to neutral will set up MMF's in the same direction in the three legs so that the only return magnetic path will be the long leakage path through air. In consequence the effects of balanced d-c components will be negligible. The substation transformers supplying the radial system and the network transformers come in this class, which explains why the network systems experienced no effects other than those due to voltage drop on generating station buses, which, in turn, had been caused by the large increase in reactive demand from the radial system.

The lack of noticeable effects on single-phase and shell-type three-phase transformers on the tie lines between generating stations has been explained on the basis that the lines run in a general northeast-southwest direction which may have been at right angles to the maximum earth potential gradient.

With this analysis in mind we can explore some of the other cases. Take the interconnected 69-115 kv system of the Northern States Power Company. The test data previously mentioned—which, however, were on 167 and 100 kva sizes—would lead one to expect that each ampere of direct current in the 69-kv windings of single phase transformers would cause 75 kvar increase, and each ampere in 115 kv windings would cause 125 kvar increase in excitation. Assuming an average of these two values, it follows that only about 0.75 ampere direct current in the neutral for each 1000 kva of transformer capacity would be necessary to explain the observed 30 mvar increase on about 400 mva of transformers.

The case of the transformer banks which tripped on differential relay operation requires no extended analysis. If direct current flows in one winding, it will not induce a corresponding current in the other and in consequence single phase transformers will have a steady magnetic flux in one direction which in turn will lead to saturation and increase the magnetizing component. The magnitude of this unbalanced component has been indicated in the previous discussion for a 220 kv transformer; one ampere of direct current will cause an increase of about 200 kvar in the magnetizing component which appears as an unbalance at the differential relays. Coupled with this there will be a distortion of the wave formed as indicated by the oscillograph. Insufficient data are available to permit making a statement as to the effect of this distortion on relay performance but it seems probable the effects will be generally in the direction of increasing the apparent sensitivity thus further decreasing the amount of

(*Continued on page* 374)

The Magnetic Storm of March 24, 1940—Effects in the Communication System

By L. W. Germaine

General Superintendent, Western Area, Long Lines, American Telephone and Telegraph Company

Address before the Dinner Meeting of E.E.I. Engineering Committees, Chicago, Ill., May 7, 1940

FOR many years the Edison Electric Institute and the Bell System have been closely associated in the solution of problems concerning the coordination of power and telephone plant. This association has been friendly and of unquestionable benefit to both. I appreciate the honor in your asking me here tonight to present some of the experiences of the Bell System in this discussion of the effects produced by the magnetic storm of March 24th.

The discussion of the effects of the storm in this paper will, in general, be limited to its influence on the longer toll routes. These routes consist principally of open wire and cable facilities which are supplemented by radio circuits for completing telephone communication to Europe, South America, and other distant lands.

In the sections of the country where toll service is most heavy, open wire lines have been supplanted largely with toll cables.

The interruptions to the land communication services by magnetic storms are attributed to earth currents flowing along the route of a toll line which cause a difference in potential to be impressed between the terminals of circuits on the line. During the more severe periods of the storm, voltages are developed considerably in excess of those with which the telephone plant will operate satisfactorily. The highest voltages as a rule will be experienced in those territories where the earth resistivity is highest and the voltage between offices in a given territory is, in general, proportional to the distance between them. As an illustration, the toll cable plant is so designed that it is necessary to have the repeater (or booster) stations closer together than is the case with open wire plant, and as would be expected, fewer interruptions are experienced on cable than on open wire.

The shaded areas in Figure 1 show the territories where high earth resistivity exists and where the highest voltages would be anticipated. The small dots, which for the most part are within the shaded areas, show where potentials of sufficient magnitude to operate devices provided to protect office equipment from damage by external sources of energy were experienced on March 24.

The greater portion of the communications plant operates on a metallic basis; however, a small part of our services is normally handled over grounded telegraph systems. In order to give satisfactory service, many of the latter facilities had been rearranged in the territories involved in the shaded or high voltage areas to operate on a metallic or balanced wire basis in anticipation of the disturbances which might be caused by magnetic storms.

There have been numerous magnetic storms in the past of various degrees of magnitude. None of them, however, have been as severe in their effects on communication services as the March 24 storm since the one which took place in May, 1921. At that time service interruptions occurred to about the same extent and in about the same territory as were experienced during the storm of last March.

The extent and magnitude of the storms occurring in the past have been studied from voltage readings taken at our Central Offices scattered over the entire country. In addition, during the past two years a recording meter has been in continuous use between Minneapolis and Fargo, the two points in our plant which are most frequently affected. A sample of the recording between these two points which was taken on March 24 is shown in Figure 2. This chart does not include the periods of greatest activity during the storm. Additional meters of this type are available at a number of points scattered throughout the country and are used to provide continuous data during periods of storm activity.

These data have provided valuable information regarding magnetic storms which have been useful in developing and providing plant less susceptible to interference from these storms.

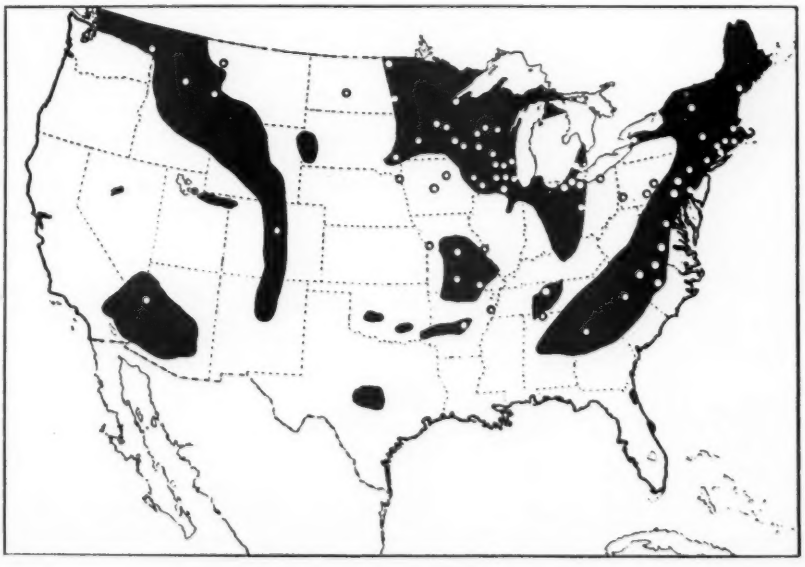


Fig. 1—Areas of High Earth Resistivity

When the magnetic storm of Sunday, March 24, 1940, developed, it immediately became apparent that it was of unusual intensity and covered a wide area, interrupting nearly all overseas radiotelephone circuits, service to ships at sea, and a number of long distance land telephone and other communication services.

While most of the serious effects on the services on the land lines took place between 9:00 a. m. and 3:00 p. m. Central Standard Time, the earth current disturbances persisted until the morning of the 25th and disturbances continued to intermittently affect overseas service for a number of days, with the Transatlantic service the most seriously affected.

Throughout the period of magnetic disturbances, radiotelephone services to South America and across the Pacific were affected considerably less than across the Atlantic, and service to the Caribbean region through Miami, and coastal and harbor radiotelephone services were practically free from interruptions. On March 24, in spite of the fact that this was the day of the most serious magnetic disturbances, about one quarter of the usual number of Sunday overseas telephone calls was completed.

As far as the land lines were concerned, regular telephone facilities in the toll cable network were affected much less than those on the open wire lines and no troubles were noted in the local telephone exchange plants throughout the Bell System.

The most seriously affected sections of the country were on the Eastern Seaboard and in the states of North Dakota, Minnesota, Iowa, and Missouri. Less serious effects were felt as far south as Georgia and as far west as Arizona, Colorado, and Montana. This is shown rather clearly in Figure 1.

During this storm there is good reason to believe that voltages in excess of 500 were experienced in certain sections but because of the operation of protective devices the maximum values were not obtained. In general, throughout the sections of the country affected, the voltages fluctuated from positive to negative with time intervals varying from seconds to minutes. In some cases the fluctuations were rather regular, but in general, no uniformity was observed.

One of the most serious effects of those high voltages was the operation of the protective devices installed in Central Offices and at the junction of open wire and cable plant. The voltages continued at such high values that in many cases the protective devices operated as fast as they were replaced, making it impossible to use the circuits. At other times the intermittent discharges across the gap of the protective devices were so frequent and severe as to make the circuits noisy and not satisfactory for service. As a matter of interest, nearly 800 protector blocks in the state of Wisconsin alone were operated and required replacement.

However, it is to be noted that, in general, the protective apparatus functioned for the purpose intended, and there was little serious damage to the telephone apparatus in the numerous Central Offices which were in the affected areas.

During the storm, failures to less than 10 per cent of the long distance telephone land circuits throughout the country were experienced; however, out of Minneapolis about 80 per cent of the long distance circuits were out of service at one time during the day; while out of Chicago, more than 200 circuits could not be used between noon and about 2 p. m.

Nearly all of the major network broadcasting facilities were affected at times during the day by noise, sharp reports, cut-outs, and scratches.

The telephotograph network which provides one of the press associations with facilities for the transmission and receiving of pictures in 30 cities throughout the United States was affected at various times during the day. However, in spite of the difficulties encountered, more than 60 per cent of the usual number of pictures handled on a Sunday were transmitted.

As this magnetic storm occurred on a Sunday, it caused less serious interruption to business through its effect on service than would have been the case on a weekday. Nevertheless, it was necessary to rapidly increase the telephone operating personnel in order to handle calls which were being delayed because of trouble, and to set up alternate channels for routing calls to points where regular facilities were disabled.

Although conditions were about normal on the following day, Monday, March 25, as a precautionary measure, outside plant work was suspended for linemen and splicers on the long distance plant. For a number of days following, the situation was watched, especially from the standpoint of safety to the personnel, because some high voltages continued periodically in certain sections of the country. As for example, a week later on March 31, 340 volts were observed between Minneapolis and Fargo.

The storm of March 24, 1940, is now a matter of history, but in passing, it has provided an opportunity for further study of the extent and magnitude of such storms, as well as a chance to try out some of the remedial measures designed to minimize the effects of the storms on the telephone plant. The experience with this storm has shown that while progress has been made in reducing interference to telephone and telegraph service, there are still problems to be solved in our efforts to reduce the effects of magnetic storms.

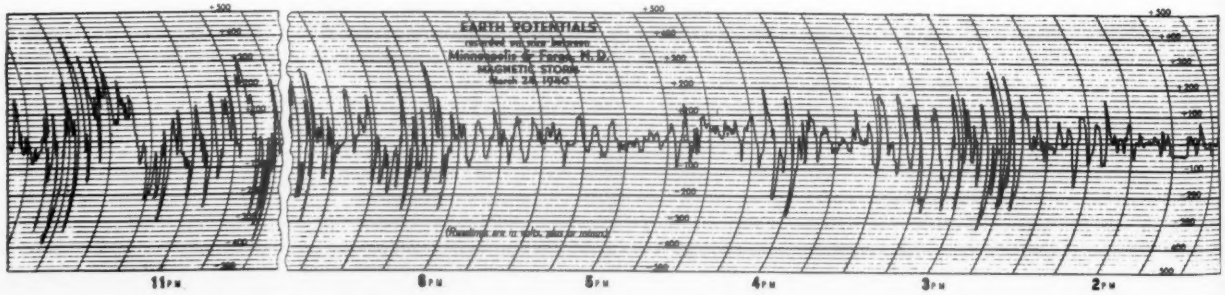


Fig. 2—Earth Potentials Recorded Between Minneapolis and Fargo, N. D., During Magnetic Storm, March 24, 1940

Standardized Metering Practices Produce Economy

Dial Constants: A Cog in the General Plan

Foreword:—In February, 1939, the EEI Meter and Service Committee published a "Standard Practice for Dial Constants of Alternating-Current Watthour Meters" designed to modernize the registers of these meters so that they would be more closely coordinated with the improved overload capacity of the modern meter.[1] The manufacturers of meters, as well as the Committee, have not been entirely satisfied with the degree of acceptance of this new standardized practice. After due consideration of all objections to date, however, the Meter and Service Committee still feels that this new standard is not only necessary but advantageous. It has, therefore, reaffirmed its decision favoring the standard as previously published. For the benefit of those who have no previous knowledge of this standard or who may have misunderstood its intentions, the Committee here re-states its case.

DURING the past several years the meter committees of the Edison Electric Institute and the Association of Edison Illuminating Companies, working in collaboration with meter equipment manufacturers, have succeeded in achieving much progress along the line of standardized metering equipment and practices. This work has included the improvement of overload as well as normal load characteristics of meters, the elimination of all but three standard sizes of meters and low-voltage current transformers, and the consequent development of a new set of dial constants for application with these long-range meters and transformers.

The extended load characteristics of the modern standard, 5-, 15-, and 50-ampere meters have provided such direct savings as the reduction of meter damage by overloads, the reduced investment necessary for the now concentrated stock of meters and parts, and the lower price of the intermediate-size meter. The development of the entirely new class of low-voltage current transformers has provided more possibilities of economy because here again only the three nominal primary sizes of 200, 400, and 600 amperes cover the complete range formerly requiring twice that many sizes.

[1] "Economics Through Simplification of Customers' Meters," February, 1939, Edison Electric Institute Bulletin.

Necessity for New System of Dial Constants

While some companies have continued to apply this new equipment in their usual conservative manner, others have sought to take full advantage of the economic possibilities. This would imply the operation of the new meters and transformers under normally overloaded conditions in some cases, so that the gaps between the sizes of the meters and transformers would be properly spanned. Thus the metering equipment may be loaded heavily during long periods of time, to avoid possible error as a result of operating the next higher size of meter or transformer at excessively light loads during the periods of lower demand.

A natural consequence of these advanced practices has been the greater possibility of register turnover, particularly in the larger sizes of meters, in a period dangerously approximating the normal reading or billing period. Since premature register turnover can cause confusion and error in billing, especially when one month's reading may have been missed, it was imperative that a new dial-constant standard be set up to conform to the other modern metering conditions and practices.

Determination of the Constants

The expected maximum kwhr registration of any meter within an indexing period had previously been computed on the basis of full-load operation for 600 hours (24 hours per day for 25 days). To maintain the same safety factor against register turnover or repetition within a reading period on the newer high-overload-capacity meters, the Meter Committee merely added multipliers to represent the multiples of full or rated load that might be applied on the meters. The following percentages of rated full load were used in determining these values:

Self-contained meters, 5 to 25 amperes	300%
Self-contained meters, 50 and 75 amperes	200%
Current-transformer meters	150%

The dial constants assigned to meters of various capacities should, by actual design, vary in powers of ten in accordance with multiples of 10,000 kwhr of expected monthly registration. But, to avoid several unreasonable exceptions that would have resulted, multiples of 11,000 kwhr were used in assigning the new series of dial constants.

Table I, then, shows the dial constants of one, ten, and powers of ten for use with standard four-dial registers on modern meters. Note particularly that any change in these constants as compared with those previously applied has resulted merely because of the desire to maintain at least the same factor of safety against register repetition under the new conditions of equipment loading, as was conservatively used in the past.

Five-Dial Registers for Elimination of Constants

The 4-dial register has for a long time been standard equipment on American watthour meters, and its continued use (with a constant of 10 on self-contained meters where the register capacity is otherwise inadequate) is deemed desirable by some companies. Others however, through their experience with constants on transformer-type and also some of the older types of self-contained meters know the error possibilities inherent in the use of billing constants. They therefore fear the spread of such multipliers to a large group of self- contained meters. For that reason, the Meter and Service Committee adopted the 5-dial register as a standard alternative arrangement for all meters which would otherwise have a constant of 10 under the new Standard. The use of 5-dial registers will eliminate the multiplier

TABLE I—STANDARD DIAL CONSTANTS FOR SELF-CONTAINED AND TRANSFORMER-TYPE METERS WITH 4-DIAL REGISTERS

Ampere Rating	*120 Volts*			*240 Volts*			*480 Volts*
	1 El.	*2 El.*	*3 El.*	*1 El.*	*2 El.*	*3 El.*	*2 El.*
			Self-Contained Meters				
5	1	1	1	1	1	1	1
10	1	1	1	1	1	10	10
15	1	1	1	1	10	10	10
25	1	1	10	1	10	10	10
50	1	10	10	10	10	10	10
75	1	10	10	10	10	10	10
			Current Transformer Meters				
100	1	10	10	10	10	10	10
120	10	10	10	10	10	10	10
150	10	10	10	10	10	10	100
160	10	10	10	10	10	10	100
200	10	10	10	10	10	100	100
250	10	10	10	10	10	100	100
300	10	10	10	10	100	100	100
400	10	10	100	10	100	100	100
500	10	10	100	10	100	100	100
600	10	100	100	100	100	100	100
750	10	100	100	100	100	100	100
800	10	100	100	100	100	100	100
1000	10	100	100	100	100	100	100
1200	100	100	100	100	100	100	100
1600	100	100	100	100	100	100	1000
2000	100	100	100	100	100	1000	1000
2400	100	100	100	100	100	1000	1000
5000	100	100	1000	100	1000	1000	1000
10,000	100	1000	1000	1000	1000	1000	1000

10, and make all self-contained meters direct reading. Operating companies that have already standardized on the use of 5-dial registers to eliminate multipliers, report that no difficulties due to 5-digit readings have been experienced in their billing procedures. The 5-dial registers are now available from all the American manufacturers of watt-hour meters.

The proponents of the 4-dial register point to the advantages of continued use of a long-standard product, and fear the confusion and errors that might result from a sudden change from 4-digit reads to 5-digit reads on some of their meters. Thus, there are two existing schools of thought, each of which has valid reasons for its opinion founded in the desire for optimum economical and accurate operation. The Committee felt, therefore, that the alternative arrangement for use of 4-dial register with constant 10 or the 5-dial register without multiplier was only a fair compromise to provide in the standard system of dial constants.

Provision for Universal-Register Practice on Transformer-Type Meters

The new dial-constant standard does not exclude, but rather provides for the alternative use of the universal or self-contained-type of registers on meters used in conjunction with instrument transformers. (This is not shown in tabulated form because of the large number of possible combinations.) In this now fairly widespread practice, the constants of 10 or powers thereof are replaced by multipliers which are the current-transformer ratio, or the product of the current- and potential-transformer ratios where both kinds of transformers are used.

Conclusion

In its work for the standardization of metering equipment and various practices for use in conjunction with the newly-developed equipment, the Meter and Service Committee has in mind the ideal of an integrated plan, all parts of which are properly coordinated for optimum economy, practicability, and efficiency in rendering an equitable metering service. Thus, the long-range low-voltage current transformers were conceived to fit in smoothly with the extended-load-range characteristics of the standardized meters, and the system of dial constants has in turn been revised to make the register capacities safely adequate for the increased registration when the meters are operated under the heavily-loaded conditions sometimes necessary.

The Committee can go no further than to develop such standardized equipment specifications and application practices, and to secure agreements from the manufacturers to supply products to conform to the standards. Beyond that, the realization of the potential economies is entirely dependent upon the degree of cooperation offered by the individual operating companies that can apply the standardized metering plan. Undoubtedly, in some cases locally-favored practices must be altered or entirely sacrificed in order to make possible an ultimate and more general improvement. The meter manufacturers cannot be expected to follow through on their agreements unless there is a fairly universal adoption of the new standards. Since the whole metering program hinges together, the amount of resultant benefit depends entirely on the general acceptance and conformity with the new dial-constant practice, as well as the standardized meters and transformers with which it is to be applied.

Magnetic Storms

(*Continued from page* 364)

will occur for 20 years. But we can look at the record.

Terrestrial magnetic records extend back for nearly a century. During that time about eight great magnetic storms, comparable in violence with that of March 24, 1940, have occurred, an average of one great storm for each sunspot-cycle (see Table 1; in this Table some of the data were from compilations by S. Chapman and J. Bartels prepared for their treatise "Geomagnetism," now in press). Judging the future by the past great magnetic storms may be expected at the rate of one a decade. Our records go further than this. They show that, including magnetic storms of all intensities, their frequency follows the 11-year sunspot-cycle, lagging behind it by about two years (see Fig. 6). Incidentally, this and related phenomena, such as radio transmission, are the only terrestrial effects which are known to be controlled by the sunspot-cycle.

Such is the contribution which the science of geomagnetism has to offer to the engineering profession. Our evidence does not recommend that drastic steps be taken to minimize the effects of magnetic storms on power and communication lines, for it assures that such effects as occurred last March will rarely be repeated. Yet it is interesting to remark that no one would have thought 200 years ago, when magnetic storms were first discovered, that some day these mysterious natural phenomena would make themselves felt in nearly every civilized home.

Consumers Power Company Dedicates Its New John C. Weadock Station

THE electric power resources of industrial Michigan were further reinforced with the completion of Consumers Power Company's new John C. Weadock Station near Bay City, which was formally dedicated June 20. The steam plant begins operations with one 35,000-kw turbo generator; a second identical unit, for which furnace and boiler have already been built into the structure, will be installed soon. The Weadock Station then will equal the capacity of the Bryce E. Morrow Station near Kalamazoo, which ranks second among the 50 generating plants of the Consumers system.

Mr. Wendell L. Willkie, then chairman of the board of Consumers Power Company and president of Commonwealth and Southern Corporation, made the dedicatory address at the open-air ceremonies attended by many utility company officials and industrial leaders from the Middle West and the East. Mr. John C. Weadock, senior counsel for Commonwealth and Southern Corporation, in whose honor the plant was named, responded.

Mr. Willkie said the new plant, costing $7,000,000, was "a symbol of two things, a man and a system . . . an example of what private enterprise has done for America." He declared that the Consumers Power Company was equipped to meet any power demands of the national defense program. Existing plants are being worked only to 75 per cent of capacity, he said.

Mr. Weadock stated that 80 per cent of the cost of constructing the building went for labor, and that the plant will use daily 13 times the amount of water pumped by the Bay City waterworks. He emphasized that "It (Consumers Power Company) will continue the plant's use in public service, and I am sure that its treatment of both the public and its employees will square with reason."

The dedication had special significance for citizens of Bay City because it was there that Mr. Weadock began his legal career 57 years ago. About 5500 persons, it was estimated, responded to the company's invitation to inspect the plant during the afternoon, and thousands more made the tour during the following three days. Mr. Weadock and Mr. Willkie also spoke at a meeting of the Bay City Chamber of Commerce in the evening.

The unit now in operation in the plant is a tandem-compound turbine designed for steam pressure of 800 lb. and temperature of 850 F. The generator is hydrogen cooled and operates at a speed of 3600 r.p.m. Hydrogen cooling increases the efficiency of the generator by more than one per cent at full load, and two per cent at half-load. The generator can be operated with air as the cooling medium, but its maximum load is then limited to about 50 per cent of the maximum capacity of the unit.

The plant is one of the most efficient in the country. Because of slightly better condensing water conditions, it is expected to better the 0.83 lb. of coal per kwhr operation of the Morrow plant. With coal costs reduced by water transportation, it is planned to operate at 80 per cent load factor. With only the initial turbo-generator in operation, the Weadock plant will use 100,000 tons of coal a year, which will be brought in by lake boats and unloaded on a storage dock. For steam condensation purposes 50,000 gal. of water a day will be pumped through the plant and discharged into Saginaw Bay through a canal constructed for the purpose.

The main plant building covers a ground area of 23,600 sq. ft. and rises to the height of a 10-story building. Its chimney, looming 245 ft. in the air and illuminated at night, will serve as a landmark for shipping on both Saginaw River and Saginaw Bay. The United States Weather Bureau has established a storm signal station on the roof.

Power generated at the John C. Weadock Station will be made available to Bay City, Saginaw, Flint and, through Consumers Power Company's statewide interconnected transmission system, to the entire territory served by the company, including most of the Lower Peninsula of Michigan outside Detroit.

Consumers Power Company and Commonwealth & Southern Corporation officials and operating staff of the new John C. Weadock generating station at Bay City, Mich.

Form A

*Case No. .....
Date of Accident.....
Time .....

EDISON ELECTRIC INSTITUTE

420 LEXINGTON AVENUE, NEW YORK CITY

Accident Prevention Committee

REPORT ON CASE OF ELECTRIC SHOCK

This information is sought by the Accident Prevention Committee for confidential use in an analytical study of electric shock cases, to be made in collaboration with scientists attached to institutions of research, for the advancement of technique in the application of Artificial Respiration and after-treatment of the injuries. Name of injured with actual locations are not required. Please mail reports, in *duplicate* to the Secretary, Accident Prevention Committee, Edison Electric Institute, at the above address. *Reports are desired on all important cases, fatal, non-fatal, and whether or not there was unconsciousness.*

I Occupation of Injured .....Age..... Height..... Weight.....
Physical Condition Before the Shock .....
Clothing Worn .....Dry.....
Wet: Perspiration..... Other Source.....
Rubber..... or Leather..... Shoes..... or Boots..... Condition .....
Weather Condition .....Type of Work .....

II What was Injured Doing .....
Type of Equipment .....Location .....
Description of Circuit.....Frequency.....
(Phase) Voltage .....Voltage to Ground.....No. of Phases .....
Contact Made Between.....

III Current Entered Body: Right Left.....; Current Left Body: Right Left .....
Duration of Contact .....How Cleared From Circuit.....
Did Injured Cry Out or Call For Help.....
Conscious When First Observed.....
Breathing When First Observed.....: Gasping.....; Shallow.....; Rapid.....; Weak.....
How Long Did Breathing Continue.....When Did It Stop.....
Any Rhythmic Motion of Edges of Nostrils (Lasts only few minutes) .....
Color of Skin: Pale.....; Red.....; Bluish (Like veins on back of hand) .....
Any Bleeding..... When..... From What Part of Body.....

IV Pole Top Resuscitation: By Whom Given..... Result .....
How Soon Applied..... For How Long.....Time to Lower.....
Prone Pressure Resuscitation: By Whom Given.....Result .....
How Soon Applied.....For How Long.....Till Rigor Mortis..... At .....
When Did Injured Make First Voluntary Movement .....
Did Injured Fall .....How Far .....
Was Injured Treated Until Recovery at Place of Accident.....
When Moved to Hospital.....Condition .....
When First Seen By Physician.....Medication Given .....

V Description of Injuries .....
First Aid Treatment of Injuries .....
Medical Treatment .....
.....Burn Emollient Used.....
Probable Duration of Lost Time Due to Accident.....
Any Residual Symptoms After Return to Work.....
.....

Note: Please make report promptly for accuracy of essential details in Sections I to IV. Do not hold report for completion of Section V. Use back of form for any additional pertinent information.

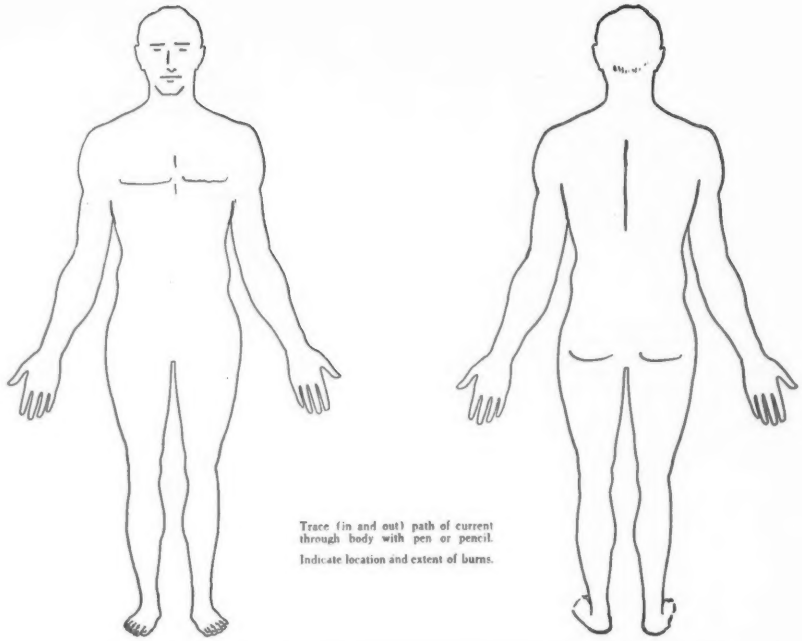
***To be assigned by Secretary, Accident Prevention Committee, E.E.I.**

Submitted By .....

Address .....

.....

(Over)



Trace (in and out) path of current through body with pen or pencil.
Indicate location and extent of burns.

Please use this space for furnishing pertinent information not covered by questionnaire.

Front and Back of Field Report on Case of Electric Shock, Form A

Copies of this form are now available at Institute Headquarters and copies will be sent in the near future to all member companies and to the various other agencies that can render service to this investigation by submitting reports on cases of electric shock of which they have knowledge.

Resuscitation Review Board

IN the May issue of the EEI BULLETIN, on page 234, announcement was made by W. R. Smith, Chairman, Accident Prevention Committee, of the appointment of a Resuscitation Review Board, and the personnel of the board was given. Dr. H. B. Williams, Dalton Professor of Physiology, Columbia University, is Chairman of the Board.

Dr. R. R. Sayers, formerly with the National Institute of Health, is now with the Bureau of Mines, and the following correction should be made in the list of personnel as given:

Dr. R. R. Sayers, Acting Director, Bureau of Mines, Washington, D. C.

The following name should be added:

Dr. P. A. Neal, Acting Chief, Division of Industrial Hygiene, National Institute of Health, Washington, D. C.

In his message to Edison Electric Institute member companies concerning the Board, Chairman Smith said:

"It is requested that all electric utility company representatives who have any responsibility for such a matter as this familiarize themselves with the contents of the Field Report Form, particularly Section III, in order that there shall be an understanding of the details on which information is especially desired. Field Report Forms will be available at Institute Headquarters in the near future."

and to which he now adds,

"Reproductions of the front and back of the Field Report, Form A, are reproduced on the opposite page of the BULLETIN. Copies of this form are now available at Institute Headquarters and copies will be sent in the near future to all member companies and to the various other agencies that can render service to this investigation by submitting reports on cases of which they have knowledge.

"As the Field Report form states, reports are desired in duplicate, and when request is received at Institute Headquarters for them, they will be sent in sets of three so that a copy may be retained in the file of the company or person submitting the report. Reports are desired on all cases, both new and old, in accordance with paragraph A, (a) to (d) under Procedure (see May BULLETIN). It is, therefore, requested that those who have knowledge of cases, on which information is sufficiently accurate to be significant, obtain forms from Headquarters and make reports."

Better Copy Contest Winners Announced at PUAA Convention

PUBLIC utility prize-winners in the annual Better Copy Contest of the Public Utilities Advertising Association were announced at the Association's annual convention at the Palmer House in Chicago on June 24 and June 25. E. K. Hartzell of the East Tennessee Light and Power Company, Bristol, Tenn., president of the Association, presided.

This contest is the oldest organized advertising competition in existence today. This year sixteen national awards were made to thirteen companies in seven states. In addition, there was regional competition prior to the national contest and regional awards were won by forty-six companies in twenty-five states.

The list of national awards, as announced by T. H. Spain, of Newark, N. J., chairman of the Better Copy Committee, is as follows:

Classification No. 1—Public Relations Newspaper Advertising—Consolidated Edison Company of New York, Inc.—for advertisement with headline "How the Community Benefits from Consolidated Edison's Million-Dollar-A-Week Taxes." Classification No. 2—Electric Load Building Newspaper Advertising—Pacific Gas and Electric Company, San Francisco, Calif.—for newspaper advertisement with headline "You Can Plan It This Way." Classification No. 3—Electric Merchandise Newspaper Advertising—Indianapolis Power and Light Company, Indianapolis, Ind.—for advertisement with headline "Shucks—Anybody Can Cook On An Electric Range." Classification No. 4—Gas Load Building Newspaper Advertising—Amarillo Gas Company, Amarillo, Texas—for advertisement with headline "Let Gas Do The 4 Big Jobs." Classification No. 5—Gas Merchandise Newspaper Advertising—Washington Gas Light Company, Washington, D. C.—for advertisement with headline "Amazing New Gas Ranges Win New Freedom for Women." Classification No. 6—Campaigns—Consolidated Edison Company of New York, Inc.—for campaign "It's Only A Penny." Classification No. 7—Transportation Newspaper Advertising—Cincinnati Gas and Electric Company, Cincinnati, Ohio—for advertisement with headline "Going To Town With Electricity." Classification No. 8—Employe Magazine—Niagara Hudson Power Corporation—for publication "Niagara Hudson News." Classification No. 9—Employe Newspapers—Cincinnati Gas and Electric Company—for publication "O-K News." Classification No. 10—Bill Enclosures—Southern California Edison Company, Los Angeles, Calif. Classification No. 11—Direct Mail Advertising—Boston Edison Company, Boston, Mass. Classification No. 12—Special Booklets, Pamphlets, Etc.—Michigan Consolidated Gas Company, Detroit, Mich. Classification No. 13—Electric Window Displays—Consolidated Edison Company of New York, Inc. Classification No. 14—Gas Window Displays—Southern California Gas Company, Los Angeles, Calif. Classification No. 15—Outdoor Advertising, Consolidated Edison Company of New York, Inc. Classification No. 16—Radio Advertising—(First) Pacific Gas and Electric Company, San Francisco, Calif. (Second) Consolidated Edison Company of New York, Inc.

Harold J. Rowe of the Iowa Electric Light and Power Company, Cedar Rapids, Iowa, was elected president of the Association at the convention. Other officers elected are as follows: first vice-president, Al C. Joy, Pacific Gas and Electric Company, San Francisco, Calif.; second vice-president, Clara H. Zillessen, Philadelphia Electric Company; third vice-president, Thomas H. Spain, Public Service Corporation of New Jersey; secretary, H. W. Olcott, Bozell and Jacobs, Indianapolis, Ind.; treasurer, Dale Remington, Wisconsin Public Service Corporation, Green Bay, Wis.; director for one year term, E. K. Hartzell; directors for three-year terms: Ted Ferguson, Dallas Power and Light Company, Dallas, Tex.; J. V. Macdonald, Boston Edison Company, Boston, Mass.; and Howard F. Weeks, Consolidated Edison Company of New York, Inc.

Utility Men Honored By Universities

Four men prominent in the utility industry received honorary degrees from American universities at this year's commencement ceremonies.

P. S. ARKWRIGHT, president, Georgia Power Company, was awarded an honorary Doctor of Laws degree by Emory University. The citation read, in part: "Outstanding business man of the southeast; civic leader; loyal churchman; for your wise counsel in civic affairs; for your ability . . . to secure the wholehearted cooperation of your entire organization because of your sympathetic understanding of their problems; for your recognized leadership in all worthwhile philanthropic, educational and religious movements; we confer upon you the degree of Doctor of Laws."

HORACE P. LIVERSIDGE, president, Philadelphia Electric Company, received the honorary degree of Doctor of Engineering from Stevens Institute of Technology.

HUBERT C. BLACKWELL, president, Cincinnati Gas and Electric Company, was awarded the honorary degree of Doctor of Engineering by Purdue University.

JOHN W. CARPENTER, president, Texas Power and Light Company, was made an honorary Doctor of Laws by Texas Technological College.

Dealer Cooperation Scores in New York

THE results of the outstanding utility-dealer cooperative selling plan of Consolidated Edison System of New York were announced at a luncheon held at the Hotel Astor, New York City, on July 8. E. F. Jeffe, Vice-President in charge of commercial operations, was the recipient of many complimentary remarks by President C. E. Wilson of General Electric Company, Bruce Barton, President of Batten, Barton, Durstine & Osborn and others who spoke to an audience of approximately 1200 dealers, distributors and guests who met to celebrate the occasion, and to share in the congratulations for this commendable achievement.

During the four months' campaign there were 375,000 appliances sold to 130,000 homes.

In reviewing the progress of the campaign, Col. Oscar H. Fogg, Vice-Chairman of the Board of the Consolidated Edison Company, stated that $60,000 had been earned in bonuses by employees of the company over and above their salaries and that $100,000 in sales taxes had resulted.

As a tribute to Mr. Jeffe, Mr. Wilson presented him on behalf of the manufacturer and distributor group, a gold vacuum cleaner similar to the one that had been sold in the group of appliances offered in the campaign, the other items being an IES lamp and automatic iron.

Further Progress

(*Continued from page* 342)

that additional ratings will be available very shortly. No doubt, this waiting period has been helpful to utilities since it provided an opportunity for thorough studies to determine how the standard transformers may be applied to the best advantage in each situation. In this way, the operators should be in a position to make immediate use of the standard transformers without confusion.

Following publication of its First Report, the Joint Committee embarked on the next step of its assignment and reports good progress in the preparation of its Second Report. This Report will cover single-phase, pole-type transformers, rated 100 kva and below, 15,000 volts and below.

Farm Week at the New York World's Fair August 12-18

THE two exhibits of the electric utilities at the New York World's Fair, the Electrified Farm and Forward March of America, look forward to greeting thousands of visitors from the rural areas during Farm Week at the Fair, August 12-18, inclusive. All national farm organizations are taking part in the observance and the program is expected to draw a large rural attendance.

The calendar of events for the week follows:

Monday—Farm Press Day

Tuesday—Farm Products Day

Wednesday—Farm Progress Day

Thursday—Farm Women's Day

Friday—Organization Day

Saturday—Farm Boys and Girls Organizations Day

Sunday—Farm Folks Day: general program with addresses by farm leaders.

Magnetic Storms

(*Continued from page* 366)

actual unbalance necessary to cause relay tripping.

Some thought has been given to the effects of direct currents on the ratio and phase angle of instrument transformers but all of the test data so far examined suggest that the effects are of secondary importance. Instrument transformers generally operate at comparatively low magnetic flux densities and in consequence they are far less susceptible than power transformers to the disturbing effects of superimposed direct currents. Relatively large d-c components are necessary to make a 5 per cent change in ratio of current transformers or to cause a similar error in the ratio of potential transformers.

No effort has been made in this discussion to explain the source of the direct currents; this is left to one of the other speakers on this program.

Rights of the Eye

(*Continued from page* 355)

today and tomorrow. My final thoughts for you are these:

1. I believe success of a most satisfying sort has been yours.

2. You must not, because of this success, fail to realize that you must hold it. Indeed you must recognize certain failure to utilize some of your best assets like the light-meter, visibility meter and photo cell controls. Designs of fixtures are still too much exponents of art and not enough of hygiene in home lighting.

3. Not only must you hold present ground but you must be prepared to advance as science moves forward. I have indicated certain desirable directions for research.

4. As you advance you will want to bring in other groups on a wider front, always keeping the same philosophy of service and human conservation as at present. New recruits must be better guided and taught the advantages of complete cooperation.

5. You must plan for coordinated research for solving problems not yet fully in hand, at, I think, certain places where cooperation is possible and the situation is right. This angle you have restricted and in some instances, I believe, not planned too well. Do not try so much for exclusive variations as for the general advance of the whole movement. Individual benefit is greater, and senseless, costly competition on little things blocks larger steps forward.

6. I feel sure that both the scientific-professional groups, educators and others want to cooperate with you, realize the benefits from what you have done and hope that your future may be even more valuable to health, happiness and humanity.

Luxury Spending

In 1939, states the National Industrial Conference Board, the following expenditures were made for "luxuries":

Alcoholic beverages	$3,577,000,000
Cigars, cigarettes, etc.	1,763,000,000
Confectionery, ice cream	922,000,000
Non-alcoholic beverages	577,000,000
Perfumes, cosmetics	229,000,000

In contrast to these, the total amount spent for electricity in the home was $795,584,000. The American people spend for liquor nearly five times as much as they do for electric service; for tobacco, more than twice. More money goes for sweets than for electricity. The American public spends as much for soft drinks, perfumes and cosmetics as it does for electric service.

PERSONALS

WENDELL L. WILLKIE has resigned as president of the Commonwealth and Southern Corporation following his nomination on June 27 as the Republican candidate for President of the United States. Mr. Willkie has also resigned as a Trustee of the Edison Electric Institute.

JUSTIN R. WHITING was elected by the directors of The Commonwealth and Southern Corporation and Consumers Power Company on July 17 to fill the vacancies created in the two corporations by Mr. Willkie's resignation. Mr. Whiting becomes president and a director of The Commonwealth and Southern Corporation and chairman of the board and a director of Consumers Power Company.

Mr. Whiting has been associated with The Commonwealth and Southern Corporation and its predecessor corporations since 1912.

Born at St. Clair, Michigan, in 1886, he received his law degree from the University of Michigan in 1907 and began practice in Port Huron, Michigan. He moved to Jackson, Michigan, in 1908 and there first represented a company affiliated with predecessors of The Commonwealth and Southern Corporation. In 1917 he became a partner in the law firm of Warren, Cady, Ladd and Hill in Detroit, but four years later returned to Jackson and organized the firm of Whiting, Kleinstiver and Aubrey. This firm represented many of the important industries in that section of the state.

In 1932 Mr. Whiting was elected president of the Michigan State Bar Association, of which he is still a member. He is also a member of the Association of the Bar of the City of New York and of the American Bar Association. He came to New York in 1933 and joined Mr. John C. Weadock in the firm of Weadock and Whiting, general counsel for The Commonwealth and Southern Corporation. He succeeded Mr. Wendell L. Willkie, who had been elected to the Commonwealth and Southern presidency.

CHARLES W. KELLOGG has been granted a 90-day leave of absence from his duties as president of the Edison Electric Institute in order to serve as consultant to the subcommittee recently appointed to advise the National Defense Advisory Commission on electric power problems.

JOHN C. PARKER, vice-president, Consolidated Edison Company of New York, will serve in a similar capacity, as will an engineering officer from both the Army and the Navy.

Arkansas Power and Light Company has announced the election of three new vice-presidents. They are W. E. BAKER, treasurer; CAPT. FRANK M. WILKES, general manager; R. E. RITCHIE, assistant to the president and manager of the Little Rock division.

Mr. Baker has been associated with Harvey Couch, president of Arkansas Power and Light, since 1911. He was elected treasurer of the company in 1922 and is also a director. Mr. Wilkes joined the organization in 1919 as commercial manager. He later served as operating superintendent and as general superintendent. In 1927 he was made general manager and elected a director. Mr. Ritchie began in 1923 as chief clerk to J. L. Longino, then vice-president and general manager. He became assistant to Mr. Couch in 1927 and manager of Little Rock division in 1935.

Three other promotions in the company were also announced. Q. C. SHORES, assistant to President Couch, was made executive assistant to the president and executive vice-president. J. L. BODIE, auditor, was promoted to assistant secretary and assistant treasurer. CHARLES T. EVANS, formerly engaged in special promotional work, becomes special assistant to the president.

MELVILLE T. CHANDLER has been elected secretary of the Consolidated Edison Company of New York, succeeding FREDERICK W. JESSER, who has retired.

Mr. Chandler began his career in 1915 as an office boy for the United Electric Light and Power Company. He became secretary of this company in 1931 and, when it was consolidated with the New York Edison Company, was made assistant secretary of the latter company. New York Edison became part of Consolidated Edison in 1936, and Mr. Chandler was made assistant secretary of the new company and manager of its General Office Service Department.

Mr. Jesser began 51 years of utility service as a stenographer with the Mount Morris Electric Light Company in 1889. Ten years later that company was consolidated with the Edison Electric Illuminating Company, and Mr. Jesser headed the Stenographic Department. He became secretary of New York Edison in 1924. In 1936 he was elected assistant secretary of Consolidated Edison, rising to the position of secretary in 1938.

A. C. JOY, advertising manager, Pacific Gas and Electric Company, has been elected president of the San Francisco Advertising Club.

GEORGE R. DAVISON has retired from his post as engineer in the Production Department of the Boston Edison Company after 35 years of service with that organization. At a dinner recently his associates in the company presented him with a watch as a testimonial of their esteem.

MURRAY F. GILL, since 1937 vice-president of the Kansas Gas and Electric Company, has been elected president and general manager of the company and also reelected as a director. As president he succeeds L. O. RIPLEY, who had held the position since 1933. Mr. Ripley will remain on the board of directors in a consulting capacity.

COL. FRANK E. BARR, Wichita division manager since 1924, was elected vice-president and assistant general manager of the company and was also named a director.

Mr. Ripley had been chief operating executive of the company since its organization in 1909, when he was named vice-president. Long active in civic affairs, he has been president of the Kansas State Chamber of Commerce and of the Wichita Chamber of Commerce.

Mr. Gill entered the utility business with the Texas Power and Light Company, which he served in various capacities from resident engineer to assistant chief engineer. In 1928 he joined the Pennsylvania Power and Light Company. He went to Wichita in 1937.

Col. Barr spent two years in the grain business before entering the Kansas Gas and Electric organization. The World War and a re-entry into the grain business interrupted his service until 1924, when he returned to Wichita as division manager.

(Continued on page 376)

The American Way of Work

(*Continued from page* 326)

thing happened in these topping machines to make the first row of blades fail. Stronger blades were made and they failed. The knowledge of the art up to that time did not explain the phenomenon which was occurring.

We needed a method for getting measuring instruments into the turbine and right up to the blade to see what was happening. It was no small assignment to give our research engineers—to get into the interior of a turbine revolving at high peripheral speeds with pressures of 1200 lb. per sq. inch and temperatures of 900 deg. F. But they did it.

Then we needed a powerhouse to try out a complete turbine, not just a laboratory type of turbine but a full-sized turbine which will put power on the lines. The Philadelphia Electric Company, one of your member companies, recognized this as an industry problem, joined us in this research and installed the unit in the Schuylkill plant.

We have already learned a great deal that is new from this research, and are incorporating this knowledge in our designs. We are proving these designs in this full-scale topping turbine operating under central station conditions.

What this experimental turbine contributes to the forward march of our industry will be a tribute to the cooperative enterprise of both branches. It is an example of private enterprises cooperating in research which will benefit a whole industry and ultimately the whole public.

No one in a gathering like this has to be sold on what research, progressive engineering and intelligent sales promotion have meant to our industry. They have placed the electric motor in almost every home and the electric lamp in practically every room in America. This is what the "American Way of Work" has accomplished.

If we are asked for a notable example of the progress of our industry, what better illustration could we give than our basic product, the electric lamp bulb? Today it has about the same amount of glass, copper and wire it had at the time of its discovery. At its start the lamp was a competitor of the candle and oil lamp. After fifty years of research and development, it is a competitor of daylight. We light Broadway, we light our ball parks, our highways and our buildings until today there is hardly an activity man cannot carry on as well at night as in the day time. We can do this due to the developments of research laboratories.

Sometimes we do not fully appreciate how large a part of our facilities is devoted to these strictly non-productive activities. In our company, 10 per cent of our investment in plant facilities consists of laboratories, test equipment and service facilities devoted almost entirely to the advance and improvement of the electrical art.

These vast facilities of our company and of other companies such as ours are not in reality the simple business furniture of the electrical manufacturers. They are the facilities of the whole electrical industry which we, as manufacturers, hold in trust for the industry.

The keystone of our research down through the years has been to accomplish ends which were practical; for example, to produce lower-loss steel for transformers, higher capacity circuit interrupting devices, more efficient lamps or more enduring insulation—but always to accomplish these objectives by thorough methods. Our research has been a tedious painstaking route to progress. For every way we have discovered to do something, we have probably discovered one hundred ways not to do it.

The research laboratories of companies like ours have been available to all utilities for solving our common problems. Utilities and manufacturers have pooled their ideas to develop new equipment. Together we have explored new fields for load building to the end that our industry would continue to grow. This has been done far more efficiently than would have been the case if one of us alone had attempted to carry these developments forward.

We electrical manufacturers can well be proud of the faith the utilities have placed in us. We hope our record of accomplishment justifies that trust. Because we have faith in the future, we are enlarging our engineering and research facilities. We are increasing our efforts to promote the increased use of electric power.

This is the American Way of Work for our business. It is our public trust to earn and to justify the confidence of the American people. Our problem is to give the public the best electric service the world affords, and never to be satisfied that it cannot be improved.

The fact that electricity has become so vital a part of our civilization is the greatest reward that any of us can ever hope for. This is the American Way of Work.

CONVENTIONS AND MEETINGS

SEPTEMBER

4-6 Pennsylvania Electric Association, Bedford Springs Hotel, Bedford Springs, Pa.
9-12 Illuminating Engineering Society, Essex and Sussex Hotel, Spring Lake, N. J.
16-17 Wisconsin Utilities Association, Accounting Section, Lawsonia Hotel, Green Lake, Wis.
25-27 Indiana Electric Association, French Lick Springs Hotel, French Lick Springs, Ind.
26-27 The Empire State Gas and Electric Association, Westchester Country Club, Rye, N. Y.

OCTOBER

7-8 Electrical Equipment Committee, EEI, Jefferson Hotel, Richmond, Va.
7-10 American Gas Association, Atlantic City, N. J.
14-16 Transmission and Distribution Committee, EEI, Henry Grady Hotel, Atlanta, Ga.
27-Nov. 1 National Electrical Manufacturers Association, Waldorf-Astoria Hotel, New York, N. Y.

NOVEMBER

11-12 Wisconsin Utilities Association, Electrical Section, Commercial and Technical Divisions, Pfister Hotel, Milwaukee, Wis.

Personals

(*Continued from page* 375)

M. H. MONTROSS, since 1933 manager of the Wisconsin Public Service Corporation's Wisconsin Valley division, has been named a vice-president of the corporation. He is also a director. Mr. Montross began his work with the Wisconsin utility companies as a district manager for Wisconsin Valley Electric Company in 1925. Previously he had held utility engineering positions at Toledo, Ohio, and Gary, Indiana.

G. A. FREEMAN, for the last year acting head of the sales department of the Commonwealth Edison Company, has been elected vice-president in charge of sales to succeed the late Edward W. Lloyd.

OFFICERS AND COMMITTEES OF THE EDISON ELECTRIC INSTITUTE

1940-1941

OFFICERS

C. W. KELLOGG, *President*
420 Lexington Avenue, New York, N. Y.

PAUL M. DOWNING, *Vice-President*
Pacific Gas & Electric Co., San Francisco, Cal.

J. E. DAVIDSON, *Vice-President*
Nebraska Power Co., Omaha, Neb.

A. H. KEHOE, *Vice-President*
Consolidated Edison Co. of New York, Inc., New York, N. Y.

W. E. MITCHELL, *Vice-President*
Georgia Power Co., Atlanta, Ga.

H. S. BENNION, *Vice-President & Managing Director*
420 Lexington Avenue, New York, N. Y.

F. H. NICKERSON, *Treasurer*
Consolidated Edison Co. of New York, Inc., New York, N. Y.

MAE B. WOODS, *Secretary*
420 Lexington Avenue, New York, N. Y.

OPERATING COMMITTEE

Chairman, C. W. KELLOGG, New York, N. Y.

E. R. ACKER, Central Hudson Gas & Electric Corp., Poughkeepsie, N. Y.

J. M. BARRY, Alabama Power Co., Birmingham, Ala.

H. C. BLACKWELL, The Cincinnati Gas & Electric Co., Cincinnati, Ohio.

H. B. BRYANS, Philadelphia Electric Co., Philadelphia, Pa.

W. H. BURKE, Ebasco Services Incorporated, New York, N. Y.

C. L. CAMPBELL, The Connecticut Light & Power Co., Hartford, Conn.

F. L. CONRAD, The United Light & Power Service Co., Chicago, Ill.

J. E. DAVIDSON, Nebraska Power Co., Omaha, Neb.

R. E. DILLON, Boston Edison Co., Boston, Mass.

PAUL M. DOWNING, Pacific Gas and Electric Co., San Francisco, Calif.

E. T. GUSHEE, Union Electric Company of Missouri, St. Louis, Mo.

A. H. KEHOE, Consolidated Edison Co. of New York, Inc., New York, N. Y.

WILLIAM KELLY, Buffalo Niagara & Eastern Power Corp., Buffalo, N. Y.

FRANK MCLAUGHLIN, Puget Sound Power & Light Co., Seattle, Wash.

W. E. MITCHELL, Georgia Power Co., Atlanta, Ga.

F. H. NICKERSON, Consolidated Edison Co. of New York, Inc., New York, N. Y.

J. F. OWENS, Oklahoma Gas & Electric Co., Oklahoma City, Okla.

W. H. SAMMIS, The Commonwealth & Southern Corp., New York, N. Y.

CHESTER C. SMITH, Kansas City Power & Light Co., Kansas City, Mo.

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